ILLUMINATING ENGINEERING

APRIL 1955

Outdoor Decorative Lighting Techniques
More on Measured Utilization Factors
IES Officers and Committee Listing
Luminous Flux Calculations
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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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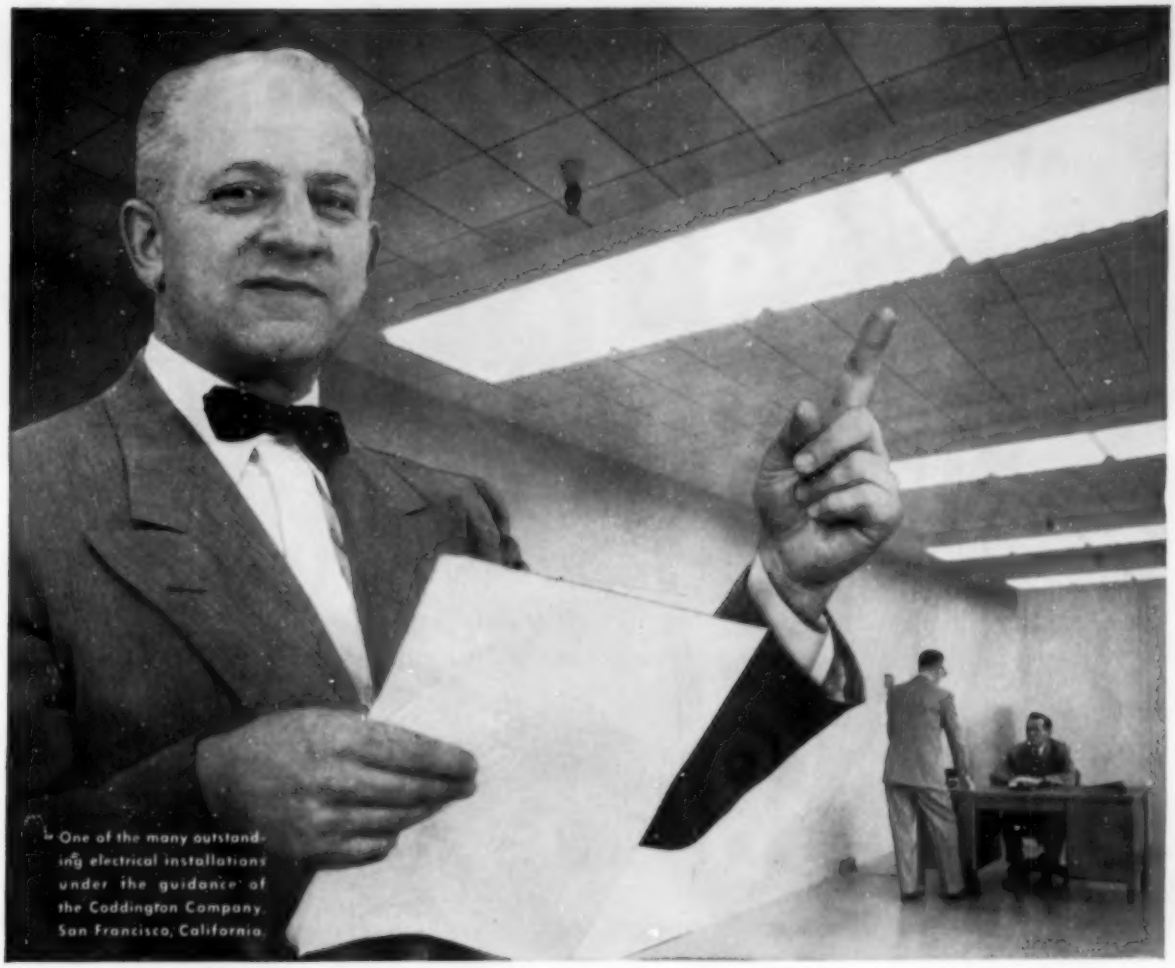

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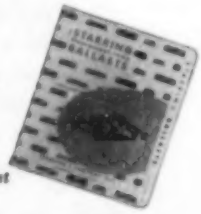

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

APRIL
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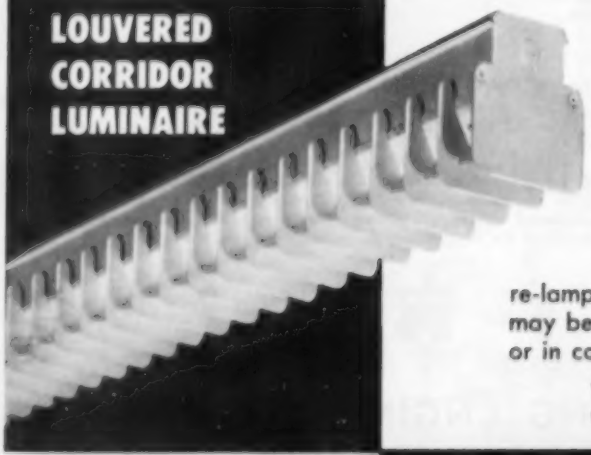

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Outdoor Decorative Lighting Techniques

By ROY A. ESHELBY

The general principles of some of the applications of decorative outdoor lighting are discussed as a means of illustrating the wide scope of this field, together with the applications of newer light sources and media available. Some feature items from the United Kingdom Illumination Program for Coronation Year are reviewed in detail.

THE TERMS decorative lighting and floodlighting, for the purpose of this paper, refer with one exception to the use of light in various forms and in conjunction with other suitable materials as an outdoor decorative media. Floodlighting except as it is applied for utilitarian purposes such as the protection of property and for general lighting is in fact synonymous with decorative lighting as a subject.

Decorative lighting is so large a field that most lighting engineers must at some time or other be concerned with one or more of its many aspects. This vast and ever-changing field of lighting is a challenge to the imagination and ingenuity of all in the illuminating engineering profession, more especially this year year when we are celebrating the Diamond Jubilee of Light. With new light sources and new materials to work with, the field is unlimited. Its application varies from an occasional festoon of fairy lights or a simple floodlighting scheme to extensive programs signifying an occasion of national rejoicing, for specific festivities, civic beautification or as a tourist attraction feature.

Scope

Any decorative scheme for the occasions mentioned will almost certainly involve more than just the use of light. In general the basic plan is developed so that the decorative scheme devised will be attractive by day but made even more effective after dark by the use of light.

It is obvious, therefore, that right from the initial planning stage the lighting engineer must play an important part in formulating the overall plan; the use of light must be integrated with the use of draperies, bunting, garlands, structural elements and other decorative media. It must also be used to the greatest advantage to enrich natural scenic beauty, gems of architecture and specific permanent features.

Whatever the nature or size of the program, it is most essential that the basic design be in good taste because such features inevitably result in extensive publicity, intended or otherwise, and the reputation of the community concerned will benefit or suffer as a result.

If the program is to be extensive, its success will depend to a large extent upon the co-operation of all interests in the community, business, social and religious groups, catering, entertainment, transportation, etc. It is essential that the planning of the project co-ordinates all points of view.

As an annual event such plans may become a seasonal attraction or be used as a means of extending a season; some holiday resorts have used this emthod as an attraction only after the warm summer weather has ceased to draw visitors to the location. As an attraction feature such programs should not be "over-worked" by covering too long a duration. They should be in operation for specific periods of time, depending on their purpose. To retain their popularity, they should also be flexible and progressive, incorporating changes of layout and new features added periodically.

Basically the component parts of any extensive program will involve the use of light for one or more of the following effects:

1. To illuminate structural features of special design; bridges, towers or other open type structures.
2. To complement other decorative mediums such as draperies, banners, garlands, etc.
3. Treatment of buildings, landmarks, statues, etc.
4. Effect lighting of waterfalls, fountains, public parks and gardens, flowers and trees.
5. For static or animated set pieces, tableaux, or special illuminated motifs appropriate to the occasion.
6. Specific indoor events.

British Coronation

For the celebration of the Coronation of Queen Elizabeth II in June 1953, the decorative treatment of London's Mall, effective in its simplicity, undoubtedly produced the show piece of the Coronation route. The four triumphant arches spanning

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 13-17, 1954, Atlantic City, N. J. AUTHOR: Northern Electric Co., Ltd., Montreal, Canada, Registered Lighting Engineer, I.E.S. (U.K.).

Figure 1. The Mall, London, England during Coronation celebration, June 1953. Triumphal arches are lighted by 500-watt, 150-watt and 75-watt reflector lamps. Banner poles by 150-watt and 75-watt reflector lamps. Photo courtesy Ministry of Works, U.K. Crown copyright reserved.

the carriageway were the dominant feature and their decoration relied to a large extent upon their structural elements (Fig. 1).

The entire structure 90 feet high was constructed of tubular members with lattice type infilling and finished with a paint of high reflectance in the traditional colors of gold and silver.

The openness of the design was as effective by night as by day, differing only in appearance by the fact that in daylight it was dark against light, whilst at night it was light against a dark background.

Visual continuity between the four arches spanning the Mall was provided by a series of poles carrying banners and surmounted by a crown. These wooden poles were 40 feet high and each carried four red banners with the royal cypher in yellow. These banners were suspended from four cross arms, in the shape of trumpets. In each of the four right-angles formed by the banners, vertical wires carried silvered balls of varying sizes suspended over the lighting fittings.

The method of lighting was surprisingly simple and was achieved inexpensively by the use of reflector type lamps, suitably concealed.

Two 500-watt lamps 12 feet from the base of each leg illuminated the upper portion of the arch, the coronet and the silver balls. Lighting of the lion and unicorn was achieved by twelve 150-watt lamps located at the base of the motif and to pick out the spike surmounting the whole structure two 75-watt lamps had to be used, mounted in the ball of the finial.

At night the framework intercepted the light projected vertically from the lamps below and produced a brilliant outline to all the features, whilst the lattice infilling was less bright owing to its flat finish. The effect of this light and shade contrast gave the required molding. No light reached the reverse side of the lion and unicorn so that when the emblems were viewed at right angles to the Mall only the bright outlines were seen, providing the effect of lighting with luminous tubes.

The reflector lamps which were so extensively used, not only in the Mall but in many other situations, proved their worth for these forms of lighting. Their physical size enabled a powerful light beam to be projected from within a much smaller space than that which would be required by a reflector and lamp combination of the same light output. Initial costs were lower and the difficulty of finding storage space after the event was minimized.

No provision for weathering was necessary, apart from preventing ingress of water into the lamp holders as the 500-watt lamps were made of hard glass. The 150- and 75-watt sizes were not, however, available in hard glass and the standard pattern when hot would have been fractured by rain, unless provided with some form of protection. In this case it was provided by means of a special silica grease applied to the face of the lamp, which prevented water making actual contact with the glass.

The lighting of the banners was achieved in a similar manner using 150-watt lamps, concealed in

Figure 2. Statue of Eros, London. At left by day, at right by night. Illumination is from 876 12-, 20- and 36-watt lamps, operated on series circuits of 24 or 35 volts.

a decorative metal spinning supported on a cross-arm between and slightly below each of the four banners. The weather protection in these units was provided by means of a disc of heat-resisting glass, as this gave mechanical protection to the lamps, which was required at this low level, besides acting as a water shed.

In the base of the crowns were four 75-watt lamps projected upwards, providing the high light necessary to form the luminous link between the arches. These 75-watt lamps were silica grease treated and the necks were sprayed black to prevent the filaments being seen from below.

It would seem incredible that the wonderful spectacle produced in the Mall by the illuminated arches and banners could have been accomplished by such simple equipment. The explanation for this lies in the method of construction and types of materials employed, together with the application of correct angular relationships between the light sources and the objects illuminated.

The treatment of the statue of Eros was another excellent example of the handling of structural elements and one which demonstrates also the close co-operation between the designer and the lighting engineer to obtain effectiveness both by day and by night. This is a delicate statue often damaged by revellers on festive occasions and for this event the idea was conceived to surround Eros with a golden cage. By day this glittering gold structure was indeed a most attractive feature but no lighting equipment could be detected without very close examination, although the entire framework was outlined with bare lamps. At night, the scene was even more spectacular when its 876 clear, colored and frosted lamps transformed the cage of gold into a scintillating spectacle of light (Fig. 2).

This unit was fed from the standlard 230 volts a-c supply through a 60-ampere double-pole fused switch and a 12-circuit distribution panel. The wiring was then carried out with rubber covered cable through special terminal boxes, designed and painted to blend with the decor.

Seventy-five series sub-circuits fed the different sections of the structure operating at 24 or 35 volts. The lamps were all of the same physical size but the correct perspective was obtained by the use of clear, frosted and colored lamps of 12, 20 or 36 watts mounted in bakelite lamp-holders, suitably weatherproofed by rubber sleeves. The total loading of the unit was approximately 12 kilowatts.

Thoroughfares

The project undertaken by the Regent Street Association, which comprises the business interests of London's "Fifth Avenue," produced through a spirit of co-operation a most outstanding decorative scheme, giving this regal thoroughfare an individuality both simple and dignified (Fig. 3).

The scheme incorporated the English Rose as the basic theme. It appeared in the design of the

Figure 3. Above — Regent Street, London, during Coronation celebration. This project, decorating the entire length of the three-quarter mile thoroughfare used 1000 Chrysaline illuminated devices of various types, together with 160 floodlights housing two 1000-watt projector lamps to floodlight upper portion of buildings, draperies and bunting.

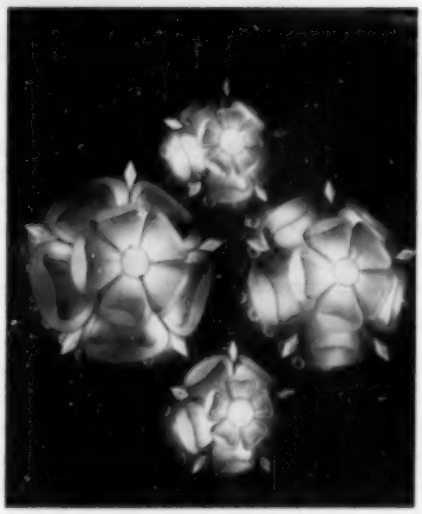

Figure 4. At right, Chrysaline illuminated device. Translucent plastic material 3 feet and 5 feet in diameter is lighted from within by four to six 60-watt and 100-watt inside frosted lamps.

draperies hung against every available column between windows on both sides of the street. It appeared also in a most dramatic form as an illuminated motif made of Chrysaline (Fig. 4). This is a new application of a plastic material which may be sprayed upon a basic frame of almost any shape. The material forms a hard, weatherproof translucent shell which may be illuminated from within and color effects are produced by treating the material with lacquer or the use of colored lamps. To obtain an even more attractive result, lamps of several colors may be used connected to dimmer circuits to provide changing color sequences.

In this particular project, 1000 illuminated Chrysaline roses, five feet and three feet in diameter were used, together with 100 similar devices in other forms, using four to six 40-, 60- or 100-watt inside frosted lamps.

In addition to the green and pink vertical draperies, a red, white and blue valance extended along the cornice of each building while at balcony level, gaily colored flower boxes provided the final touch, displaying specially grown flowers along the entire length of the street; every street lighting standard also received decorative treatment.

The result achieved was so charming and alive with color by day that the lighting engineer had only to provide the means of maintaining the same effect when night descended upon the city.

This was no small task, but it was achieved by the use of 160 floodlights, each housing two 1000-watt projector lamps, and specially designed to avoid glare to pedestrians and motorists. The units were located at fifty-foot intervals and mounted on existing ledges fifteen feet above the sidewalk. From these units the decorations covering the entire upper portion of the buildings (a height of approximately 50-60 feet) were effectively illuminated.

The illuminated Chrysaline devices were used on the lower portions of the building not covered by

Figure 5. Magnet House, London. Uses Chrysaline illuminated devices and bare lamp designs, coordinated with hardboard cutouts, draperies and garlands. Total loading: 45 kw. Photo courtesy General Electric Company Ltd.

the floodlights. All lighting equipment was connected by a continuous system of rubber covered cable, fed back to the mains at one or two positions in each block of buildings. The system was operated by time switches set to switch on at 10 p.m. and off at 2 a.m.

Buildings — Floodlighting

The treatment of buildings for decorative effects calls for something more than the prosaic results so often produced by standard white floodlighting. This is particularly true of the treatment of buildings of historical interest and unusual architecture, when white light so often reveals deterioration of the masonry and accentuates discoloration of the face of the building. These problems are often easily overcome through the judicious use of colored lighting effects, emphasizing the charm and dignity of the building and at the same time camouflaging any defects.

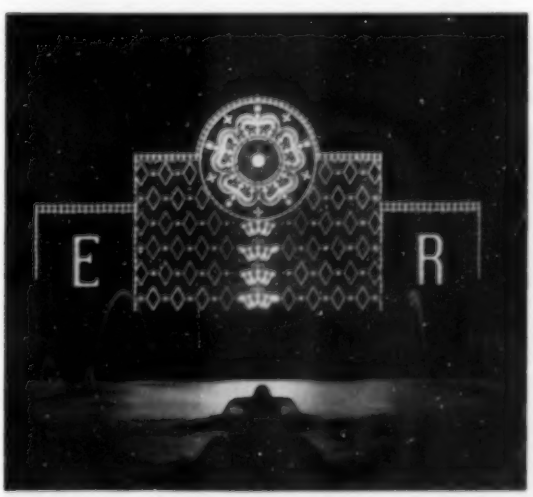

Figure 6. Lumascope — 120 feet by 60 feet comprised of 5000 lamps, arranged in colorful designs of crowns, diamond, Fleur-de-Lis, flowers, etc. Control is arranged to give a lighting change every three seconds, without a repeat for ten minutes. Total loading: 80 kw. Photo from Strand Electric and Engineering Company Ltd.

However, most color screens or lenses required with incandescent light sources have high absorption factors necessitating the use of expensive high wattage projectors and correspondingly high power consumption, resulting in high capital and operating cost.

These factors have been overcome to a great extent by the use of projectors using electric discharge light sources providing natural colored light of various hues, by virtue of the fact that the light output falls within specific wavebands of the visible spectrum, producing colored light characteristic of one or more specific wavelengths and of varying intensities. In some cases, the lamp tube is tinted to accentuate a specific color. The tinting being in the glass itself and of a similar color to the light emitted by the lamp still provides a much more efficient source of colored light than a conventional incandescent unit with a standard color screen.

Effects available include the characteristic greenish blue color of standard mercury, the monochromatic yellow of sodium, red from a special four-foot 400-watt neon lamp and four-foot 250-

Figure 7. City of Blackpool, England features an annual "Illuminations Program" during the Fall months, attracting an average of three million visitors, extending its season several months past its normal summer holiday period. Show at left is the 520-foot tower using 10,000 10-watt lamps, and the illuminated arch with changing color sequence. See also Figs. 8, 9 and 10.

watt mercury lamps with tinted glass tubes provide a light green or dark blue effect.

Because of the high lumen per watt output of these light sources an economical and highly efficient source of colored light is obtained. These lamps are used extensively in Europe for many floodlighting applications. The latest development in this field is the application of colored fluorescent floodlighting effects, which may be controlled by dimmer circuits providing a continuously changing color sequence.

These light sources provide tremendous scope in the application of the artistry of floodlighting, providing a harmony of color so essential to decorative lighting. A red brick building with stone masonry could be particularly effective illuminated from the natural red light of a neon flood with just a suggestion of white light to pick up the outline of the light-colored stonework.

Buildings — Decorative Lighting

When the location of the building does not permit the application of standard floodlighting techniques, an entirely different approach is possible.

Figure 8. Elizabeth II tableau at Blackpool. Designed as a stained glass window, it uses colored translucent cellulose acetate sheets, each section being lighted separately in the manner of a jig-saw puzzle.

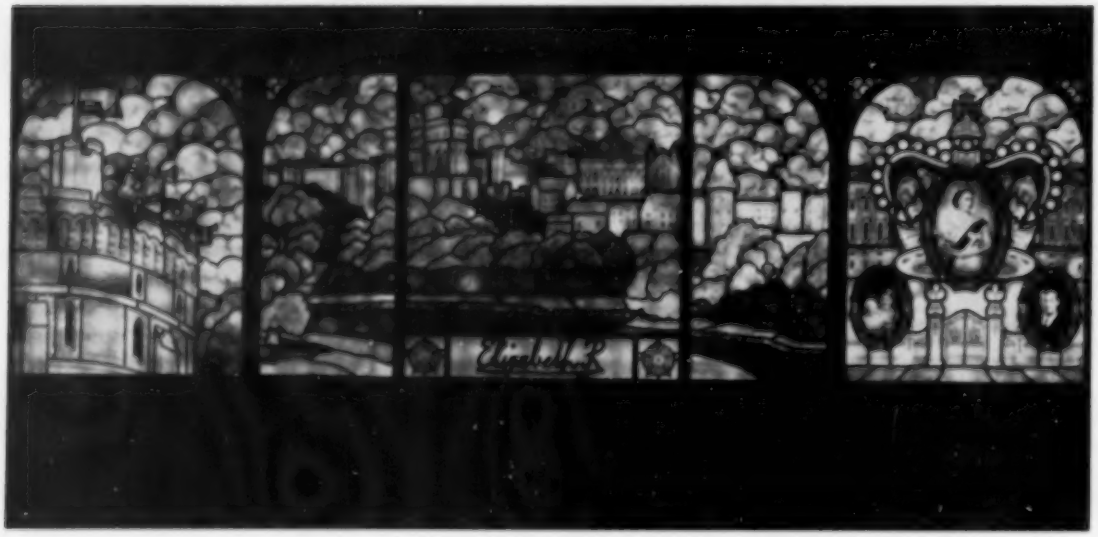

Figure 9. Blackpool, England — Tableau "History with a Smile." Characters "drawn in light" effect is obtained by boxed cutaway channels, backed with white acetate sheet and illuminated by 15-watt lamps, operated by drum controller.

This was well illustrated by the efforts of one of the business houses to add to the festive air of London's streets during the Coronation period. The focal point of the design consisted of a frame bordered in red, white and blue and studded with fifty-six illuminated Chrysaline roses. The center-piece featured an illuminated motif set within the frame and comprising the Royal Cipher surmounted by a Chrysaline crown, against a background of criss-crossed wires, with scintillating lamps at the apex of each intersection (Fig. 5).

On each side of the center-piece a staggered design of red, white and blue Fleur-de-Lis was flanked by floodlit banners of imperial blue. At first floor level twelve hardboard shields carried Chrysaline motifs of alternate crowns and thistles, while scallop-shaped bunting was draped along the parapet between them and along the top of the building with clusters of three lamps at each point of intersection.

The whole scheme was rounded off at each corner of the building by flags and Tudor roses surmounted by a crown.

In all, over one thousand lamps were employed with a total power consumption of forty-five kilowatts.

Figure 10. Blackpool, England — "Kartoon Kollonade" giant Chrysaline lanterns and cutout figures are illuminated with half-coated 15-watt lamps. Colored festoon strip interconnecting lighting standards.

Parks and Gardens

Natural scenic beauty to be found in the parks and gardens of most cities offers an ideal medium for the use of light to enhance their natural charm but particular care should be exercised in planning the illumination of such locations.

A decorative lighting display in a park is perhaps one of the most satisfying projects for the lighting engineer to design, since the natural surroundings and background provide a perfect setting and an ideal basis for picturesque schemes of various designs. Few "props" are required and such a project need not be unduly expensive.

Floodlighting of trees and shrubbery provides interesting shadow and silhouette effects. Care must be taken, however, to locate and conceal the lighting equipment so that glare from the light source does not detract from the effect. Mercury lamps produce an excellent effect for such applications.

For floral layouts white light should always be used to enhance the natural color of the blooms.

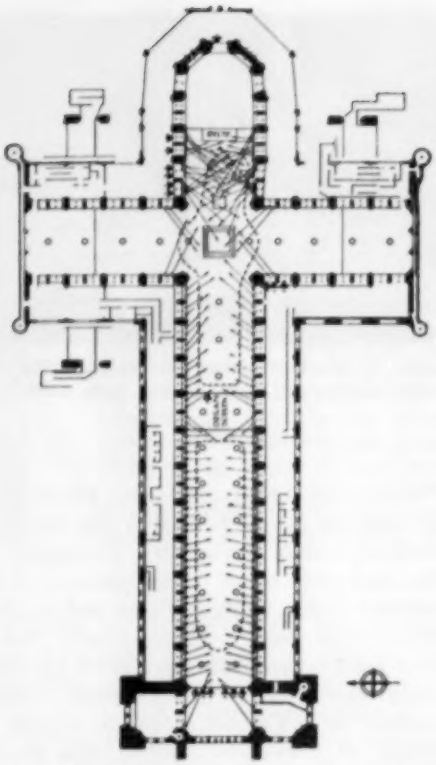

Figure 11. At left, Westminster Abbey during Coronation of Elizabeth II. Chandeliers have been modified for the occasion and carry six 500-watt Photopearl lamps. Special projectors at height of 60 feet house 1000-watt and 750-watt projector lamps. A level of 120-footcandles is obtained for television and motion picture purposes.

Figure 12. At right, Westminster Abbey, Ministry of Works plan, showing location and training of high-level projectors, positions of chandelier fittings, and television and film cameras. "Crown copyright reserved."

Mushroom or trough type units, treated to blend with the background, may be used.

When vantage points exist, providing panoramic views of the city, the layout of such locations when viewed from above should also be considered and might suggest the use of festoon strip outlining beds and pathways; when interlaced in trees, moving branches produce a pleasing twinkling effect.

Color is often advantageous to simulate or accentuate Fall tints or moonlight but here good taste is essential. Bizarre color combinations are spectacular but extreme care is most important to avoid results that become hideous and unreal.

Lakes and fountains provide an attractive medium and can become an ideal focal point of any such display. Great play can be made of illuminated artificial flowers, of fairy-tale characters set upon islands, of floating platforms where lakes exist.

Where fountains may be utilized, efficient jet control is important. With a fine mist, rainbow effects can be produced but large water drops increase sparkle. Lights should be concealed if possible and located just below water level; changing color sequences may or may not be desirable depending upon the location and nature of treatment of surrounding areas.

Thought should also be given to treatment of statues, obelisks, summer houses, shelters and the desirability of introducing illuminated pylons, birds, animals and other appropriate garden figures.

Set Pieces and Tableaux

Set pieces and tableaux may be constructed from metal, plasterboard or fireproofed plywood on suitable framing. Designs are unlimited and could include birds, animals, childish and imaginary figures, human or quasi-human characterizations and floral, geometric and abstract patterns.

Suitable basic themes are varied; they may be topical, artistic, classical or humorous. Always

popular with young and old are characters from well known folk or cartoon stories.

It should be remembered that topical subjects soon date; historical events may be appropriate for festivals and specific festive celebrations. Humor is a favorite element as such occasions are usually of the lighter vein and all appreciate a good laugh.

Considerable thought must be given to the size and shape of such features, particularly for spacious gardens or large open boardwalks, otherwise they may be considerably dwarfed by the surroundings. Creative ideas and drawing board impressions must be carefully checked and visualized with site conditions. Frequently the units need to be considerably larger than at first visualized and careful thought given at the design stage to eliminate an unbalanced effect and costly modifications at a later date.

The engineering of any such project must take into consideration the reduction of wind pressure, as far as is practical, by the shaping and streamlining of pieces, fireproofing and weatherproofing of the material, simplified maintenance and adequate grounding.

Heavy rains accompanied by strong winds can produce a continuous sheet of water over the whole structure. With displays constructed from wood there is frequently leakage which is dangerous from a handling point of view, yet insufficient to cause breakdown, whereas with metal construction grounded for safety repeated breakdown may arise from arcing to ground.

Other design problems concern the various electrical devices for control and to provide animation. These include the incorporation of time-switches, photo-electric cells, chasers, flashers and special electrically controlled drum type devices. The latter provide sequence operations and where desirable incorporate and regulate sound apparatus for tableaux requiring music or commentary to accompany light sequence.

An understanding of the importance of these problems may be better appreciated from a review of one or two specific installations.

One such feature for the Coronation, 120 feet by 60 feet, utilized 5000 lamps arranged in various designs and mounted on a framework of sheet metal, hardboard, etc., supported by a semi-permanent structure (Fig. 6). The design consisted of Crowns, Diamonds, Fleur-de-Lis, yellow and green roses and other features interconnected and operated by a specially designed drum type controller. The device was connected by 18,000 feet of cable and consumed 80 kilowatts of electrical energy.

The control was devised to exploit not only the possible combinations of the various lighting groups but also their sequential interest. Thus, the cycle although giving a lighting change every three seconds does not repeat for ten minutes. Within this period there are, in various forms, seven presentations of the five basic side patterns forming a frame around the center and thirty variations of the center build-up.

The method used ensured that the sub-cycles and main cycles formed a visual symphony and that a particular effect which may take the onlooker's eye was repeated with considerable variations and ultimately returned to its original form. Because a cycle deliberately composed and patterned was aimed at, there was no question of setting each circuit on a drum traveling at a different speed and, thereby, leaving the device to meander its way through all possible permutations, attractive or otherwise.

Two drums were used. The first, a fourteen-way was directly wired to its contactors and ran through the build-up of the center in six three-second steps ending in a three-second blackout. The second drum was a five-way building up in five three-second steps and also ending in a three-second blackout.

Contactors operated by the second drum were connected in five different sequences through electro magnetic coupler switches. At the end of each revolution of the drum, the patterns were reconnected in a different order under cover of the blackout period, the appropriate coupler being switched in sequentially.

A ratio of 6-7 of the drums provided an effective repeat cycle of 2·1 minutes but the coupler switches extended this in sequence to 10·5 minutes. All changes took place at three-second intervals and were synchronized to occur on center and side panels at the same moment.

To prevent monotony, there was a build-up in one part of the center feature in the form of seven actions, which are completed in three seconds. Also certain circuits are caused to scintillate by vibrators, these circuits being held on during the blackout period to prevent a dark void.

Large Scale Projects

The City of Blackpool, one of the most popular holiday resorts in the United Kingdom, used a different but equally impressive approach, utilizing a wide variety of special features to make up a six-mile "Illumination Program."

Dominating the entire scene was a tower approximately 520 feet to the top of the flagpole (Fig. 7). The lighting display made use of close to 10,000

ten-watt lamps in the form of festoon strip attached to convenient wooden battens, lashed to the main girders and bracing ties of the structure. The lamp circuits were mainly 100 volts with 25-volt circuits at the top balcony which is accessible to the public.

At the principal entrances to the boardwalk and other access points of the "Illuminations" route special colorful arches, some with changing colors, were used to welcome the visitor.

The boardwalk itself was truly a fantasy of light and most ingenious in its conception. Featuring Walt Disney characters throughout its length, giant lanterns hung from the streetlighting standards, while specific characters reclined upon the supporting brackets and were also suspended from the pole itself. The lanterns, made of Chrysaline, housed six 60-watt lamps, while the other features were made of plywood cutouts, artistically painted, with sixteen 15-watt half-dipped lamps on the surface, the clear lower half of the lamp effectively iluminating the background whilst the top half was appropriately colored. Colored standard festoon lamps were interconnected between the street lighting standards (Fig. 10).

Many types of set pieces and tableaux contributed to the display. Another example of originality portrayed a stained glass window effect forty-eight feet in length. This was made up of wooden frets on which were mounted colored translucent cellulose acetate sheets to represent stained glass. Each section of the window was lighted separately by a 25-watt lamp in a boxed compartment so that the tableaux could be illuminated in sections in the manner of a jig-saw puzzle (Fig. 8).

Another feature depicted an oversize blackboard with historical cartoons chalked upon the board. The characters were actually "drawn in light," the effect being obtained by cut-away channels faced with white acetate plastic sheeting and illuminated by 15-watt lamps which were operted by a drum controller, building the line drawings up in sections (Fig. 9).

Searchlights

Perhaps the most spectacular effect produced for the Coronation lighting, however, required only a source of light to illuminate one of the wonders of nature. This was the use of searchlights for floodlighting the sea, providing an exhilarating spectacle, especially in color; it is, however, only effective on surf and breakers and the climate in the United Kingdom provides few nights when wind and high tide and comfortable weather conditions prevail at the same time. However, the effect produced a magnificent sight which under more favorable weather conditions would be a major attraction feature. The searchlights housed a 2½-kilowatt high pressure mercury-vapor discharge lamp, providing a beam intensity of 12,000,000 candles.

A carbon arc searchlight with a beam candlepower of the order of 150,000,000 candles was used at the top of the tower, rotated through 360°.

Searchlights form dramatic and exhilarating backdrops for any large scale lighting program provided they are used with imagination and in sufficient quantity. They should be used systematically and not as is so often the case, as isolated units sweeping the sky in a haphazard manner.

It is possible to use color with some type of units, adding greatly to the effectiveness of the demonstration. The following indicates some of the basic patterns which may be used effectively.

CONE — From units located around the perimeter of the city, the units should be switched on with the light beam pointed vertically and slowly converging to a cone, the apex of which would correspond to the center of the city and at a predetermined height.

FAN — For units mounted in line and within close proximity to each other, each unit being switched on with the beam set to a specific point of a radius of 180°. The beams each side of the vertical would then converge upon the vertical point as the closing of a fan and re-open.

CHASING — A form of "follow-my-leader" where all beams pursue the marker beam to any point in the sky. The marker beam could be in color

CIRCLE — Each individual beam sweeping a radius of 360 degrees at predetermined angles of elevation.

PATHFINDING — The first beam sweeps the sky through a radius of 180° and finishes, pointing in the direction of the second unit; this procedure is then repeated for each unit in sequence.

The City of Blackpool Illuminations program now in its twenty-first year, is used specifically to extend the summer tourist season and is only in operation for two months in the Fall when the weather is no longer a major attraction.

The success of the program may be appreciated by the fact that the total number of visitors for the whole season — June to October — is about seven million. If it were not for the "Illuminations" attraction it would end in early September but every year, for the past five years, the Fall months have attracted an average of three million visitors to the city.

That part of the London Illuminations program sponsored by the Government operated for only seven weeks. The great public demand that the period be extended was indicative of its success;

another indication of the popularity of the Illuminations may be judged from the demands upon the city's transportation system. Special floodlighting bus tours carried a total of 175,000 people or approximately 1,000 people per hour every hour that the lights were on.

Indoor Floodlighting

No specific basic principles can be stated for the floodlighting of interiors for special occasions or special events. Each problem needs to be treated individually because of the number of variables involved. Invariably floodlighting alone is not the answer and a sound knowledge of all the basic principles of illuminating engineering plus a considerable amount of practical experience is required to evolve a satisfactory solution to the problem.

One outstanding example of interior floodlighting was that of Westminster Abbey for the Coronation ceremony (Figs. 11-12). Dr. Ward Harrison described this installation as follows: "I have not yet seen any indoor illumination to equal the lighting of Westminster Abbey for the Coronation. In that problem there were three prime requirements, distinctly individual, and almost exclusive. For the first time lighting designed to make television and color motion picture photography possible was likewise the most effective that could have been devised for viewing the great spectacle by those seated in the Abbey. For people seated at a great distance from the crowning it was just as necessary to have 120 footcandles there as it is on the stage of a theatre, and yet it was provided in a way that was infinitely more kind to the principals who took part under it for some three hours."

The lighting system installed for this historic event contrasted with that used for the Coronation in 1937, when it consisted of 500-watt reflectors situated in alternate arches throughout the length of the Nave with similar treatment around the Theatre. The illumination provided by this arrangement was of the order of 15 footcandles in the Nave and 30 footcandles over very limited areas of the Theatre.

Critical examination of photographs and films taken at the 1937 Coronation revealed that at least twice as much light would be required and more attention would have to be paid to the angles of light to provide film and photographic records worthy of the present day.

The request by the film companies to take color films of the ceremony with the greatly increased illumination necessary introduced the problem of providing this essential without discomfort by glare or temperature, both of which would be the limiting factors. In addition, it was also essential that the lighting equipment should be unobtrusive.

Experiments were carried out in conjunction with the film companies to ascertain the minimum ilumination necessary to produce a reasonably good color film and this was found to be 120 footcandles.

It was seen in the photographs and films taken in 1937 with 30 footcandles that facial shadows at times almost obliterated the features and increasing the illumination value to 120 footcandles with almost vertical lighting, would intensify this defect by increased contrast. When coronets were worn, the face of the person wearing it would appear as a black patch in an otherwise good color film. In an attempt to rectify this fault, the projectors were positioned so as to obtain an oblique angle in each direction along the axis of the Nave. It was found that this angle had to be at least 30 degrees if the shadows were to be reduced sufficiently for the features of the person to be recognizable. Owing to the long sight-line over the length of the Nave, the projectors at this angle produced a glare which would not have been acceptable. A suggestion by one of the film companies to have batteries of four 150-watt silvered lamps at low level attached to each of the piers in the Nave was tried and abandoned on account of the discomfort produced. An alternative suggestion, to use clusters of 500-watt Photopearl lamps in pendants, was also tried experimentally with encouraging results. These are photographic lamps with a life of approximately 100 hours.

To produce a good picture (in color especially) of the procession in the Nave, it was necessary to have an adequate degree of lighting, not only in the aisle but also over the assembled guests which would provide a colorful background. The pendant fittings did this admirably in addition to relieving the facial shadows satisfactorily.

An eight-light corona pendant with opaque reflectors was tried, but in addition to its industrial appearance which was quite out of place in the Abbey, it did not allow for any upward lighting which would be essential for effect if daylight was poor.

As an alternative, the Abbey chandeliers were tried, the six arms carrying the vertical lamps and shades were reversed so that the lamps could be suspended. To these arms were attached prismatic glass reflectors in which the 500-watt Photopearl lamps were placed.

This arrangement proved very successful because the Abbey chandeliers which form part of the building were retained and sufficient light, both downward and upward, was provided. It was found, however, that the satin finish of the white

glass introduced an undesirable brightness which was also out of harmony with the brass of the chandeliers. This was overcome by treating the glass with a lacquer which was fired to make the color permanent and to withstand the heat of the 500-watt lamps.

The units in close proximity to the altar were retained in their original form in order that the dignity of this part of the Abbey should not be impaired in any way. Ordinary wax candles were used.

The inclement weather on Coronation Day would normally have caused the upper portion of the Abbey to be gloomy but the upward light from the chandeliers produced a golden glow over the whole scene, thereby proving the worth of this modification and at the same time reduced the apparent brightness of the reflectors.

The use of Photopearl lamps also had the advantage of providing a color temperature of a value nearer to that desired for color filming and the average value obtained was of the order of 2970°K.

Before proceeding to a description of the high level lighting, the method of suspending the glass reflectors should be mentioned. The reflectors were designed for use with 200-watt general service lamps and supported by the normal canopy and gallery screws. A 500-watt Photopearl lamp has approximately the same dimensions as a 200-watt general service lamp but runs at a much higher temperature. It was visualized that the expansion caused by this additional heat could result in a fracture and no such risk could be taken. An inconspicuous wire cage was, therefore, designed which carried the weight of the reflector on the rim, leaving the neck complete freedom to expand and at the same time giving ample ventilation to the lamp. An almost invisible wire mesh was attached to the underside of the cage for protection in the event of lamp breakage. No fracture of lamps or reflectors did occur but this safeguard was an essential requirement.

There were two rows of eight chandeliers (each carrying six 500-watt Photopearl lamps) between the West Door and Organ Screen and these produced an illumination of 60 footcandles over the aisle and spread well over the adjacent seating. Being suspended at a height of 30 feet from the floor the fittings were not disturbing, even to those in the higher stands.

The chandeliers also drew attention away from the projectors at high level and so formed an effective "Screen."

The additional illumination required to build up the center of the Nave to 120 footcandles was provided by special projectors, at a height of 60 feet from the floor. These projectors consisted of a highly polished aluminum parabolic reflector contained in a standard floodlight housing and the lamps used were 750-watt Class B2 projector type. It was found that the cut-off angle of the reflector did not shield the direct vision of the filament sufficiently to prevent side angle glare. To overcome this, a concentric louver (or spill ring) was designed which contained a prismatic glass diffusing dish. The effect of this combination prevented the direct view of the filament from any direction and annoying stray light was eliminated.

The mouth of the projector units was covered with three-quarter-inch wire mesh in case of lamp fracture. The light loss due to the screening and protection was some 25 per cent but this sacrifice was necessary to ensure fredom from glare of exposed filaments and for safety.

The majority of the projectors were angled to approximately twenty degrees towards the organ screen. The purpose of this arrangement was that the light should fall as obliquely as possible without undue glare towards the outgoing procession, in order to assist the cameras situated over the West Door.

For convenience, special retractive slides were fitted to take the projectors and these were very useful in focusing and relamping and saved much time. These were left in position and could be used in the future for the same purpose.

The theatre presented problems more difficult of solution than those in the Nave. For example, there were four positions for cameras to be considered; two diametrically opposite each other at low level, one on the organ screen facing east and one in triforium facing west. Whereas in the Nave all projectors could be angled in one direction to serve one camera position, in this case each of the four positions had to be provided for.

It was also even more essential in this important area for facial shadows to be kept to a minimum and little assistance could be derived from chandeliers with Photopearl lamps. There were only two such chandeliers in this area, which were on either side of the Throne and practically the whole of the Sanctuary lighting had to be done from triforium level.

As the view of the projectors in the Theatre was foreshortened, it was possible in this area to increase the oblique angle to 30 degrees and so obtain cross-lighting without discomfort.

A total of fifty projectors similar to those described above were employed in the Theatre, thirty in the Sanctuary and twenty in the crossing, each containing a 1000-watt Class B2 Lamp. These projectors produced a very concentrated beam and the "spot" at floor level was about seven feet in diameter at 30 footcandles, tapering to 10 footcandles at 10 feet in diameter. It will be appreciated, therefore, that over the important areas four beams had to be superimposed. This was done where possible from four opposing positions, and the beams crossing at a height of about five feet from the floor. By this arrangement, much of the shadow was effectively cancelled out.

The lighting control was carried out from one central point above the high altar from which it was possible to observe the progress of the ceremony and to keep watch for any possible failure of the equipment or supply. In the event of mains' failure, it would have been possible to switch over the entire load to stand-by diesel driven generators in less than thirty seconds.

Acknowledgments

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The author wishes to express appreciation for the co-operation received from the following government departments and other organizations, and for permission to quote extracts from "the official report prepared by the Ministry of Works on the lighting in the Abbey and along the Coronation route."

The Chief Engineer,
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The City Engineer,
City of Westminster (U.K.)
The Illuminations and Public Street Lighting Officer,
County Borough of Blackpool (U.K.)
The General Electric Company (U.K.)
The British General Electric Company (Canadian) Ltd.
The Strand Electric & Engineering Company Ltd (U.K.)
The London Transport Executive (U.K.)
Holophane Limited (U.K.)

Lighting Is a Feature Of Model Exhibit Home

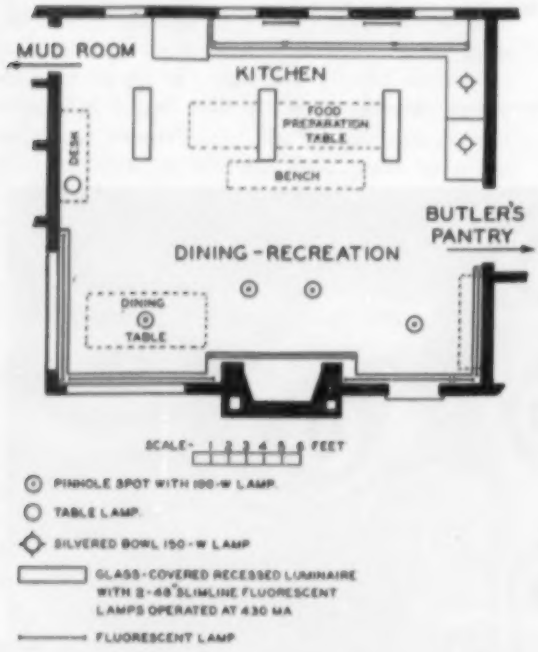
Recessed lighting could not be used in this model house because roof construction allowed only 3 inches between ceiling and roof. In the kitchen, an unobtrusive luminaire, ceiling-mounted with a wide metal frame painted to match the ceiling, provides general illumination. A twin-unit of bullet-shaped reflectors supplies additional light over the sink and food preparation area, and lights under the range hood make it easy to see what's cooking.

This kitchen is part of a model home, constructed by *Better Homes and Gardens* magazine, incorporating suggestions and ideas from a panel of readers. Lighting was planned by Mary Taepke of Detroit Edison Company.

Pine, Pewter and Modern Lighting

By MYRTLE FAHSBENDER

Food preparation area of room. Note light in cupboards with doors open. Food preparation table, shown in plan view below, was removed when photos were taken.



Illumination Levels (Average)	
General lighting in preparation area	15 ft-c
Dining table	
Cornice only	13 ft-c
Pinhole spots only	5 ft-c
Counter tops	
(cornice and under-cabinet lighting)	40 ft-c
Sink	25 ft-c
Range	20 ft-c
Telephone-planning desk	40 ft-c

A MAN runs this kitchen. But he's a man who knows what's needed in a kitchen, in all respects. He is C. C. Philippe, Host of the Waldorf. Being an artist as well, he could appreciate the desirable qualities of the white frame colonial home he was remodeling, huge other-century kitchen and all. From the old mansion-type kitchen, laundry and storeroom, he wanted to create a new room of open plan by combining kitchen, dining and entertainment area, having all modern equipment and lighting without a "laboratory look." With it all, he wanted to retain the colonial decor and atmosphere of the old home.

Remodeling plans eliminated all the existing partitions, opening up the area to a large room that is now 22 x 24 feet, not including the butler's pantry. From here, designer and lighting consultant pooled their knowledge to create the new area shown. Flooring is a blue-gray rubber tile (about 30 per cent reflectance) and the ceiling, 7 feet 7 inches, is a very light blue (40 per cent), the color having been added to the cement. The walls, base and wall cabinets, and all other wood finishes are brushed pine which was taken from an old barn on the estate. Layers and layers of old paint were scraped off to reveal the original wood. Counter tops, a happy compromise with modern convenience and colonial decor, are of heat-resistant plastic in a "rift-oak" design, almost identical with the color of the pine. One side of the room is a business-like kitchen area; the other side, which includes a large fireplace, is for dining and entertaining.

For such a large multi-purpose room, lighting problems were many. While still retaining the colonial feeling of the place, what was needed was:

1. General lighting to be controlled from three different entrances.
2. Utility illumination at the range area, sink and on the counter tops.

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Dining area

The story of an old kitchen of the "servant era" transformed into a kitchen for today's living, with lighting the chief ingredient

Detail of cornice

3. Lighting so planned that the large preparation table in the kitchen portion of the room would have acceptable illumination.

4. Pleasant, and more dramatic lighting for the dining-entertaining part of the room.

With this as a goal, here is what we did:

On the kitchen side of the room, three luminaires with ribbed opal glass covers are recessed in the ceiling, so located as to highlight the large preparation table. Each unit uses two 48-inch deluxe warm white slimline lamps operating at 430 ma.

Dropped down from the ceiling, and out from the face of the cabinets is a wood cornice (same wood as used for walls and cabinets). Mounted on the ceiling behind the cornice is a continuous run of fluorescent lighting, deluxe warm white. This arrangement directs light downward on the counter tops and into the cabinets when they are opened. For counter tops under the two cabinets, illumination is provided from under-cabinet units, so placed and shielded that they are invisible to one seated at the dining table across the room.

Concealed under the large copper hood over the range are two 150-watt silvered bowl incandescent lamps which give indirect lighting from the ceiling (which in this spot is painted white). The sacrifice in footcandle level here is felt to be justified by the increased comfort and avoidance of reflections from the highly-specular counter tops, range enamel, and stainless steel surfaces. [I.E.S. recommendation is 40 footcandles for kitchen duties at range, sink and work counters.]

In the dining-fireplace side of the room, lighting effects are purposely dramatic. Recessed pinhole downlights are used, four of them, with metal plate flush with the ceiling. All metal framing, here as with the recessed fluorescent units, is painted the same color as the ceiling. Each downlight uses a 100-watt inside frosted lamp.

To tie the two sides of the room together, so to speak, the wood cornice and fluorescent strip surrounds three sides of the dining-fireplace portion. The reflected light from the walls and drapery provides a backdrop of light against which the more concentrating downlights are used. Flexibility and "mood-setting" is offered by the lighting arrangement. Downlights alone, cornices alone, or both together, are Monsieur Philippe's choice, depending on the occasion.

Luminous Flux from a Luminaire

An Alternative Semi-Graphical Procedure for Determining the Light Flux Output of a Luminaire From Its Intensity Distribution Curve

By W. A. HEDRICH

VARIOUS procedures are available for calculating the luminous flux from a luminaire. Some are more convenient than others; some, more accurate than others. The procedure outlined here is not designed to attain greater accuracy. The changing ratio of lumens to candlepower at different angles within any given zone is inherent in the continuity of flux relative to the source and the concentric receiver — for convenience, the sphere, and is independent of the method of evaluation of flux. Yet a method[1] has been devised to eliminate the error arising from this changing ratio when computing the lumen output by the conventional zonal-constant method.

The following procedure is based on dividing the space surrounding the source into equal solid angles, thus obviating the necessity of calculating the incremental fluxes as the product of varying solid angles and changing mean intensities.

Consider an axially symmetric intensity distribution curve, the intersection of whose 90° axis with the nadir coincides with the center C of the sphere of radius R. (See Fig. 1.) Then if the great circle of the sphere is divided into equal increments of plane angle, the definition of apparent intensity of the source yields the total flux as

$$\phi_{tot} = 4\pi \left[\frac{(I_{mean})_o{}^1 (\Delta\omega)_o{}^1}{4\pi} + \frac{(I_{mean})_1{}^2 (\Delta\omega)_1{}^2}{4\pi} + \ldots + \frac{(I_{mean})_j{}^{j+1} (\Delta\omega)_j{}^{j+1}}{4\pi} + \ldots \right] \quad \text{Eq. 1}$$

in which the quantity within the brackets is the mean spherical intensity of the source, since

$$\phi_{tot} = 4\pi I_{MSCP} \quad \text{Eq. 2}$$

Both the total flux and the mean spherical candlepower are functions of two variables, the mean zonal intensity and the solid angle. The approximation clearly points out the sources of error. The latter depends upon the size of incremental plane angle used as well as upon scaling off values of intensity from which respective mean values are obtained, not to mention the sacrifice in accuracy by employing an arithmetical mean value. To obtain the total flux, a summation of incremental zonal fluxes must be effected, each of which involves a somewhat time-consuming process before the summation can be made.

Let the diameter PG of the sphere be divided into any arbitrary finite number of equal intervals distant h apart. Then the area of any zone $MNST$ is equal to that of any other zone of equal height since

$$A_z = 2\pi R h \quad \text{Eq. 3}$$

The equal area zones correspond to equal solid angles. The corresponding plane angle increments will not be equal. Now the total flux is

$$\phi_{tot} = 4\pi \left[\frac{(I_{mean})_o{}^1 \Delta\omega}{4\pi} + \frac{(I_{mean})_1{}^2 \Delta\omega}{4\pi} + \ldots + \frac{(I_{mean})_j{}^{j+1} \Delta\omega}{4\pi} + \ldots \right] \quad \text{Eq. 4}$$

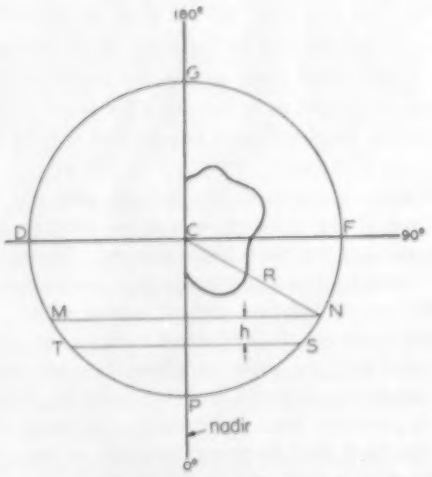


Figure 1. Axially symmetric intensity distribution curve, the intersection of whose 90° axis with the nadir coincides with the center C of the sphere of radius R.

AUTHOR: Assistant Professor of Electrical Engineering, University of Michigan, Ann Arbor, Mich.

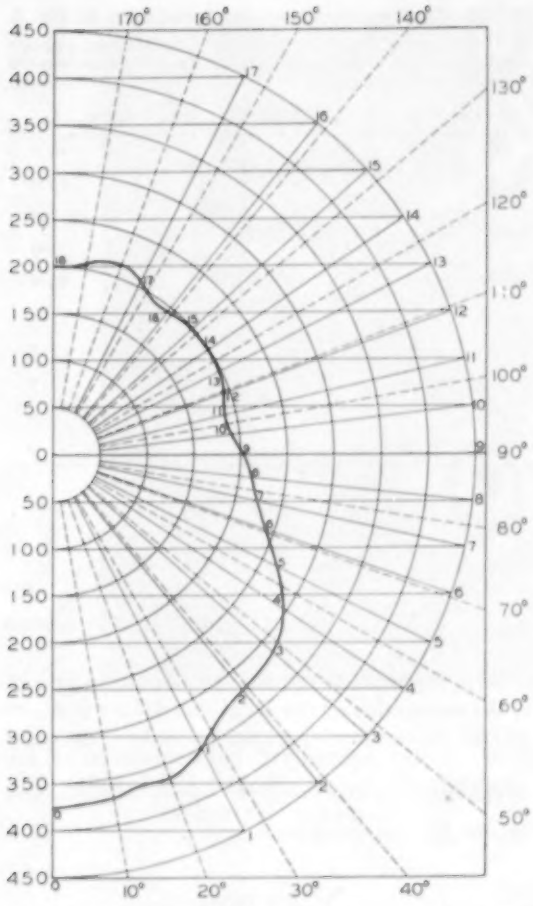


Figure 2. Candlepower distribution curve of a luminaire.

where

$$(\Delta\omega)_0{}^1 = (\Delta\omega)_1{}^2 = (\Delta\omega)_j{}^{j+1} = \Delta\omega = \frac{4\pi}{N}$$

in which N represents the total number of equal solid angle zones into which the sphere has been divided. It follows that

$$\phi_{tot} \cong \frac{4\pi}{N}\sum_{j=0}^{N-1}\frac{(I_j+I_{j+1})}{2} = \frac{4\pi}{N}\left[\frac{I_{0^\circ}+I_{180^\circ}}{2}+\sum_{j=1}^{N-1}I_j\right] \quad \text{Eq. 5}$$

The plane angles are derivable from the relation

$$\alpha = \cos^{-1}(1-2n/N) \qquad \text{Eq. 6}$$

where n is a positive integer, $(n = 0, 1, 2, 3, \ldots N)$. However, these angles need not be evaluated. It is sufficient to describe a sphere of radius R equal to $N/2$ convenient units about C as center and draw lines parallel to diameter DF, thus dividing the sphere into N equal solid angle zones. In any actual polar coordinate plot, the candlepower scale divisions may sometimes serve to delineate this unit. In general, the work is facilitated by choosing R equal to or greater than the ordinate of maximum intensity. The lines parallel to DF intersect the circle of radius R at points which mark the plane angles given by Equation 6.

TABLE I.—Flux Calculation for Distribution in Fig. 2.

Based on Zonal Constant Method					Based on Semi-graphic Equal Solid Angle Procedure	
Angle α	I_α	I_{mean}	Zonal Constant	Zonal Flux	Angle α	I_α
0°	375				$\alpha_0{}^\circ$	375
		344.0	0.0954	32.8		
10	313				α_1	333
		310.5	0.2835	88.0		
20	308				α_2	316
		319.0	0.4629	147.6		
30	330				α_3	300
		325.0	0.6282	204.2		
40	320				α_4	277
		310.0	0.7744	240.1		
50	300				α_5	262
		287.5	0.8972	257.9		
60	275				α_6	237
		257.5	0.9926	255.6		
70	240				α_7	220
		227.0	1.0579	240.1		
80	214				α_8	207
		209.5	1.0911	228.6		
90	205				α_9	205
		192.5	1.0911	210.0		
100	180				α_{10}	195
		182.5	1.0579	193.1		
110	185				α_{11}	185
		190.0	0.9926	188.6		
120	195				α_{12}	190
		197.5	0.8972	177.2		
130	200				α_{13}	195
		197.5	0.7744	152.9		
140	195				α_{14}	198
		201.5	0.6282	126.5		
150	208				α_{15}	198
		209.0	0.4629	96.7		
160	210				α_{16}	195
		207.5	0.2835	58.8		
170	205				α_{17}	212
		202.5	0.0954	19.3		
180	200				α_{18}	200

In Equation 5 the quantity $\sum_{j=0}^{N-1}\frac{(I_j+I_{j+1})}{2N}$ is the approximate mean spherical candlepower of the source, and approaches the true *MSCP* as N tends toward infinity. The total flux is a constant $4\pi/N$ multiplied by the summation of the mean intensities. Equation 5 also shows that only the mean of the intensities at 0° and 180° need be evaluated. All other intensities are merely scaled from the polar diagram and this sum added to this mean of the first and last terms.

The smaller the value of N, the greater the error in the event the distribution curve reveals relatively large values of candlepower in directions close to 0° and 180°. In such cases the value of N should be increased. Assuming that measurements were made under conditions which justify an apparent intensity within engineering accuracy as referred to the inverse square law, it is to be noted that for any given N the accuracy improves as the plane

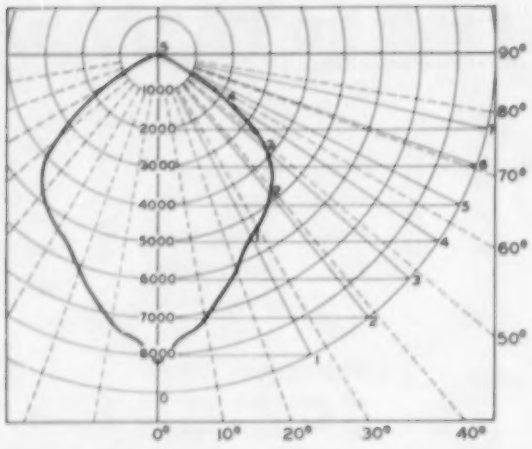


Figure 3. Candlepower distribution curve of a luminaire.

angle increments approach the 90° position so that midzone values of intensity could be used to advantage for essentially lateral distributions. However, the additional work required is not justified by the improvement in accuracy. For widely varying distributions in the vicinity of 0° and 180°, this treatment, like that of the conventional zonal constant evaluation, is in need of refinement.

A perfectly diffuse plane element, luminous on one side only, emits $\phi = \pi I_{max}$ lumens. The zonal constant procedure, using 18 equal plane angle zones, yields a result within engineering accuracy. The semi-graphical procedure outlined here, using the same number of equal solid angle zones, checks the theoretical result within two per cent.

Two illustrative problems will demonstrate the application. Consider the intensity distribution of luminaires as shown in Figs. 2 and 3. The lumen output of these sources will be computed by the zonal constant procedure and compared with the output when determined by the semi-graphical method as indicated by Equation 5.

With reference to the distribution shown in Fig. 2, the summation of the zonal flux values is $\phi_{tot} = 2918$. From the semi-graphic procedure, the mean of the first and last terms is $\frac{I_{0°} + I_{180°}}{2} = 287.5$. The sum of the remaining is

TABLE II.—Flux Calculation for Distribution in Fig. 3.

Based on Zonal Constant Method					Based on Semi-graphic Equal Solid Angle Procedure	
Angle α	I_α	I_{mean}	Zonal Constant	Zonal Flux	Angle α	I_α
0°	8200				α_0°	8200
		7725	0.0954	737		
10	7250				α_1	5500
		6725	0.2835	1906		
20	6200				α_2	4800
		5800	0.4629	2685		
30	5400				α_3	3900
		5025	0.6282	3157		
40	4650				α_4	2000
		4060	0.7744	3144		
50	3470				α_5	0
		2235	0.8972	2005		
60	1000				α_6	0
		500	0.9926	496		
70	0				α_7	0
		0	1.0579	0		
80	0				α_8	0
		0	1.0911	0		
90	0				α_9	0

$$\sum_{j=1}^{17} I_j = 3925$$

$$\phi_{tot} = \frac{4\pi}{18}(287.5 + 3925.0) = 0.698\ (4212.5) = 2940$$

With reference to the distribution shown in Fig. 3, the summation of the zonal flux values is $\phi_{tot} = 14{,}130$. From the semi-graphic procedure, the mean of the first and last terms if $\frac{I_0 + I_{a5}}{2} = 4100$. The sum of the remaining term is

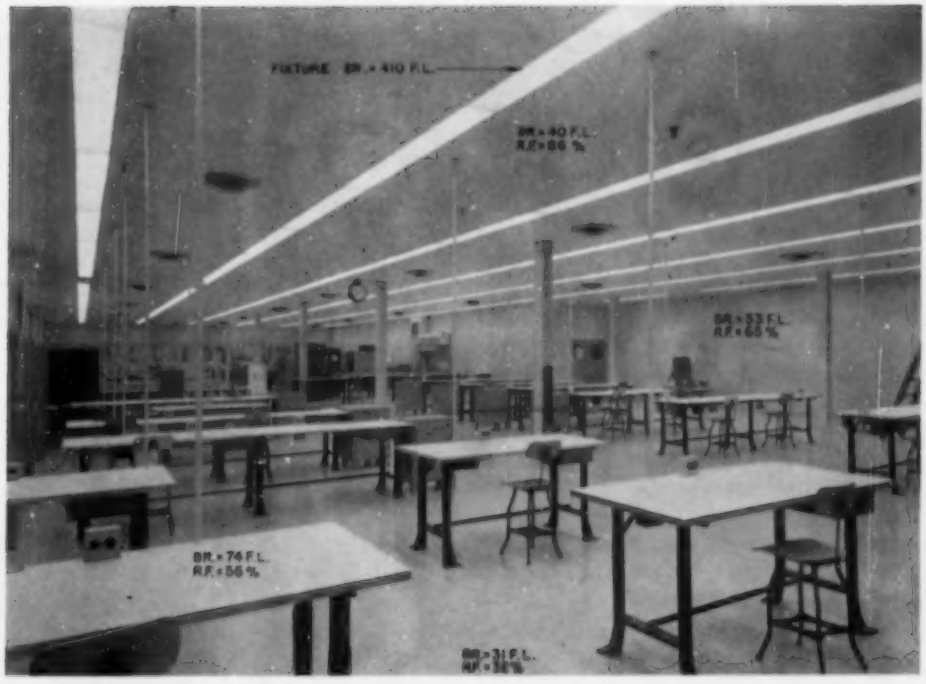
$$\sum_{j=1}^{4} I_j = 16{,}200$$

$$\phi_{tot} = \frac{4\pi}{18}(4100 + 16{,}200) = 0.698\ (20{,}300) = 14{,}169$$

In summary, if data giving intensities for equal plane-angle zones are available but not plotted in a polar diagram, the conventional zonal constant procedure is to be recommended. If the polar plot is available, the output of the source is generally obtainable with less time and effort by applying the semi-graphic method. This applies equally well to the evaluation of mean spherical intensity or mean hemispherical intensity of the source.

Reference

1. Toenjes, David A.: "A More Precise Method of Computing Zonal Lumens," ILLUMINATING ENGINEERING, Vol. XLVI, No. 7, pages 335-337 (July 1951).



I.E.S. recommended brightness ratios (or better) plus I.E.S. recommended illumination levels (or better) equals —

Lighting for Precision Manufacturing

By L. J. PETERSON

SOMEWHERE in the back of his mind every lighting engineer has a dream of working on the perfect job. To me this dream job would include the privilege of selecting every single item of the interior — finishes of the walls, floors, furniture, and in industrial areas work benches and machinery, as well as all lighting equipment. Those very circumstances came true, in the lighting for Western Electric's rebuilt plant at Hillside, New Jersey.

The item being manufactured there is a very special project. Its final perfection is so important that every item within the environment, including even the clothes of the workers, must represent ideal conditions. But especially the lighting. What is this item? Intricate repeaters which will act as booster stations every 37 miles across the floor of the ocean, for the first trans-Atlantic telephone cable. This history-making project is the joint undertaking of the Canadian Government, the British Government and the American Telephone and Telegraph Company. It will cost $35,000,000.00 and take three years to complete. The repeaters being made in Hillside will be connected in the cable, more than a mile straight down at the bottom of the Atlantic ocean. So far as is humanly possible, they must be so perfect that they will not need to be brought up again, but operate continuously, without servicing, for at least twenty years.

Likewise, so far as was humanly possible, with the knowledge available today, the lighting for this manufacturing area must also be perfect. Seeing tasks of minute size, coupled with the necessity of precision assembly called for more — much more, than a good lighting system. The entire environ-

AUTHOR: Senior Electrical Engineer, Western Electric Co., New York, N. Y.

ment must be conducive to comfortable seeing, with no compromises permitted. Moreover, "surgical" cleanliness was a prime requirement. The development engineers specified that the atmosphere of the plant must be completely free of dust, calling for an absolute minimum of dust collecting surfaces (even the workers had to don lint-free nylon uniforms), and must have rigid humidity and temperature control. All surfaces had to withstand weekly washings to maintain utmost cleanliness.

The old factory leased for the operation had two outstanding characteristics — window glare everywhere, and a generally dusty condition. To meet the new requirements, a new interior must be built within the existing structure. The lighting man's dream — perfection from scratch.

A suspended ceiling was constructed within the 200-foot square area, with final design of the new ceiling at 11 feet 2 inches. Recessed troffers were employed, using two 96-inch slimline lamps, with low brightness plastic lens as closure for the bottom of the troffer. A good brightness control was obtained, with a minimum conditioned air leakage into the attic space.

Lighting layout included continuous row lighting wherever possible. In some places it was necessary to break the runs to accommodate air ducts, monorails and structural interferences, however. Deluxe cool white lamps were used since color discrimination is required in the product being manufactured, and possibly aids also in employee reaction and morale.

With a Weston cosine-color-corrected footcandle meter, readings were 60 footcandles over the pit area, and 70 footcandles on the benches under the lower ceiling. High reflectance of the upper walls aids materially in providing almost as much light on the work in the high bay as in the low bay with the same luminaire spacing. The machine shop areas have approximately 60 footcandles general lighting. Machines are equipped with local supplementary units to comply with I.E.S. current recommended practice. Well over 200 footcandles are provided at the point of seeing.

Indirect Lighting Upside-Down

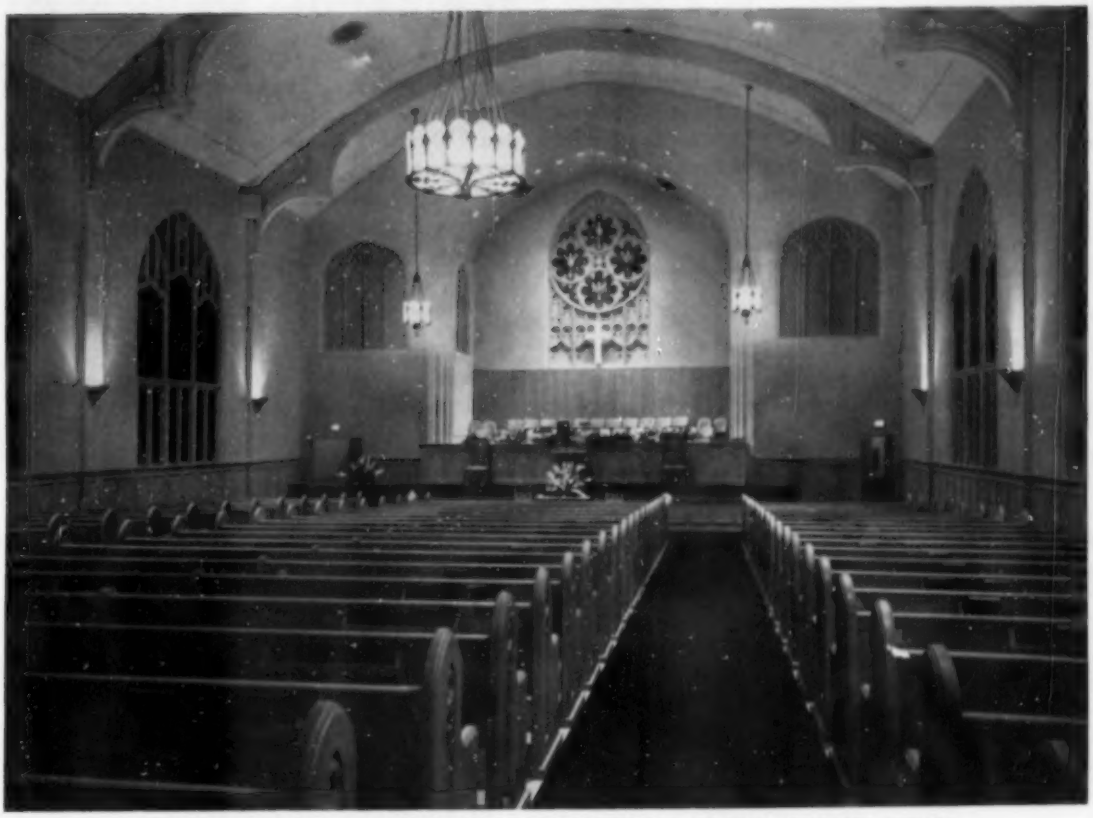
Leading illuminating engineers have recently emphasized the importance of uplighting for factories. We have followed these suggestions in millions of square feet in our plants, and like the results. At Western Electric in Hillside, I.E.S. requirements were met by making everything in the room from floors to bench tops and walls as light as possible. Inadvertently this results in indirect lighting from the floor up to the ceiling, rather than the usual condition of indirect lighting from ceiling to floor or desk tops.

BRIGHTNESS RATIOS BETWEEN	ACTUAL	I.E.S. RECOMMENDED PRACTICE	
		FACTORY	OFFICE
TASKS AND ADJACENT SURFACES	2:1	5:1	3:1
TASKS AND REMOTE SURFACES	1:1	20:1	10:1
LUMINAIRE AND CEILING	10:1	40:1	20:1
ANYWHERE WITHIN NORMAL FIELD OF VIEW	10:1	80:1	40:1
WALL, CEILING AND FLOOR	1:1	—	—

Brightness ratios as measured on the job are shown in the second column of the table. The third column gives the I.E.S. recommended ratios for industrial areas. The actual job ratios are better than recommended practice, which, of course, is in the direction desired by I.E.S. It has long been my feeling that many industrial seeing tasks are more acute than those found in offices. The fourth column of the table shows I.E.S. recommended ratios for offices. The actual job ratios still fall well below the values shown for offices. Why not? Certainly, the visual tasks for this particular job are more difficult than those in offices. Note the brightness readings also shown on the photograph, and the surface reflectance values. The fixture is the brightest object in the field of view with a reading of only 410 footlamberts. The bench top shows 74 footlamberts. Reflectance factors are shown beneath the brightness readings on the picture.

Colors used to obtain these values were: white ceiling, sea foam green walls, floors a very light gray, and bench tops ivory white.

This raises a significant point concerning the Society's theory on interflectance. In computing for footcandles for the Bench Assembly Room, which is the area shown in the photo, this particular area rates a Room Index of C. If we would have used the conventional tables our coefficient of utilization would have been .55. The interreflectance theory, with this size room having an 80 per cent ceiling, 50 per cent walls and 30 per cent floor resulted in a coefficient of utilization of .64. Based on this, our initial calculated values would be 59 footcandles against 69 footcandles. The measured initial footcandle level in this area, well after the 100-hour lamp burning period, was 95 to 100 footcandles with an expected maintained value of 75 footcandles. Since the room finishes will be washed frequently there should be very little deterioration of the reflecting surfaces. The measured value is higher than the interreflectance value because the actual reflectances are higher. It seems to me that the interreflectance method is not just a theory, and that the higher reflectances recommended by I.E.S. do contribute materially in raising lighting levels.



INSTALLATION AT FIRST PRESBYTERIAN CHURCH, CORPUS CHRISTI, TEXAS.

Lighting a Church

LIGHTING OBJECTIVE: To provide illumination for reading hymns and prayers, to highlight the rostrum and choir, and create a pleasing atmosphere.

GENERAL INFORMATION: This church measures 70 feet by 50 feet with the ceiling arched from 28 feet at the sides to 38 feet in the middle. The floor is light terazzo (33% RF); aisles are carpeted in red (13% RF); pews and railing in front of choir are blond oak (25% RF); woodwork is light green (50% RF); ceiling is white (80% RF); and the walls are pale green acoustical tile (67% RF).

INSTALLATION: General lighting is provided by (a) six lighting units (Edwin F. Guth Company #A1570) recessed in the ceiling with 6-inch diameter apertures and using 750-watt T-24 medium bipin lamps and (b) ten wall urns (Edwin F. Guth Company #A1645) mounted on the side columns. The wall urns use 200-watt lamps and have semi-concentric louvers specially designed to prevent the people in the steep balcony from viewing the lamps directly. The old chandeliers were retained for atmosphere, with the former 150-watt lamps replaced by the 40-watt size. Twelve units (Prescolite Manufacturing Corporation #750) are recessed over the choir with black concentric louvers and using 150-watt R-40 spotlamps (switched on two circuits for two levels of

(over)

A.I.A. File No. 31

illumination). Four similar units are recessed above the rostrum. The cross over the choir is illuminated by a neon strip behind the white Plexiglas. The ten-foot diameter stained glass window is transilluminated from the outside by ten 150-watt PAR-38 floodlamps, switched on two circuits for two levels of illumination. The lamps are mounted 11′8″ away from the window on a level with the bottom edge, and focused around the perimeter of the window for even distribution of light. All eighteen lighting circuits are switched by remote control from the organ.

Illumination levels are as follows:

choir	35 footcandles
rostrum	35 footcandles
church	
recessed lights only	8-10 footcandles
all lights	10-11 footcandles

Brightnesses are as follows:

small chandeliers	
sides	485 footlamberts
bottoms	15 footlamberts
large chandeliers	
sides	450 footlamberts
bottoms	140 footlamberts
walls	
3-foot level	3.24 footlamberts
7-foot level	4.38 footlamberts
directly above wall urns	335 footlamberts
20-foot level	4.8 footlamberts
behind choir	5.6 footlamberts
ceiling, above columns	6.8 footlamberts
pews, first row	3.9 footlamberts
floor, carpet	0.8 footlamberts
transilluminated window	4.2 footlamberts

Lighting designed by Carlton Whitworth, Laredo, Texas; Robert L. Vogler, Architect; H. L. Scott, Electrical Contractor.

Lighting data submitted by Robert L. Vogler, Engineer-Architect, Corpus Christi, Texas, as an illustration of good lighting practice and to aid in the design of similar installations.

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Measured Utilization Factors II

By WENTWORTH M. POTTER
ANSON H. RUSSELL

The authors have made additional measurements of utilization factor in both small and large test rooms, with individual filament and continuous row fluorescent units. Some of the results are compared with data from other sources. Direct lighting information encompasses studies of suspension distance and luminaire patterns. A new flux-ratio formula, procedure and specimen charts for ready construction of coefficient tables are presented. For filament indirect, the effect of flux distribution is considered; light-trapping is analyzed for both filament and rows of fluorescent. Upward Utilization Factors suitable for ready use are tabulated for wide-distribution individual units and continuous-rows of units at different suspensions. Explorations on vertical illumination and the effects of certain room obstructions are included.

IN A PAPER[1] presented three years ago, the authors reviewed the needs for new illumination design data and described flexible laboratory facilities for measurements in this field. Last year their paper[2] described the precautions necessary for accurate measurement and discussed the tests made in laboratory rooms 12½ feet square. Rooms of this size could be any height up to 16 feet—they included full-scale spaces at lower values of room ratio (high-ceiling, narrow rooms). In order to avoid undue distortion of the rooms due to very small scale, room ratios[3] in this series of tests were limited to 2.0 (E) for direct and 1.5 (F) for indirect. In these rooms, with many combinations of reflectance values for ceiling, walls and floor, tests were made with a variety of flux distributions and luminaire arrangements. Data from these tests were presented, and some were compared with data from other sources.

In the interim, additional measurements to supplement and extend the previously-reported data have been completed. Many of these have been made in large 30 x 30-foot laboratory test rooms (see Fig. 1) which are more favorable for rooms large in proportion to their height — room ratios[3] 2.0 (E) to 5.0 (A). Moreover, a series of tests with

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 13-17, 1954, Atlantic City, N. J. AUTHORS: Application Engineering Department, Lamp Division, General Electric Co., Nela Park, E. Cleveland, Ohio.

Figure 1. One of the test set-ups in the 30 x 30-foot laboratory test room, in which the maximum ceiling height is 13 feet. Luminaires were wide distribution indirect. No furniture is used in room during utilization tests. At lower left, section of the 16-foot track for automatic searching of one quadrant of the room.

continuous rows of extended luminaires has been conducted for both direct and indirect components of output. These data are analyzed and presented in this paper in a manner similar to that employed for the earlier data.

Direct Lighting

Wide Distribution — Large Ratio Rooms

In general, as previously shown, direct lighting measurements in the smaller test rooms agree well with the results of careful calculation. However, it appeared desirable to conduct some tests, in rooms of large proportions, with the filament RLM Dome previously described. For this purpose test rooms 30 feet square were used with work-plane at about ¼ of ceiling height. Four units were used at a time in each of three patterns so that a weighted average utilization for sixteen units could be obtained.

Values of measured utilization factor for room ratios of 2.5 (D) and 5.0 (A) are given in Table I. Calculated values for the exact room conditions used for tests are also included. As expected, they show very good agreement; it is assumed that agreement will be as good for narrower distributions and for larger numbers of units. The calculated factors were derived from the following equation previously presented:[2]

$$\text{Utilization Factor} = \text{Direct Ratio} + (1.0 - \text{Direct Ratio})\frac{h}{h'} f_1 + (\text{Floor Ratio})\, f_2$$

Where: Direct Ratio and Floor Ratio are the fractions of luminaire output directly incident on work-plane and floor respectively.

h = ceiling-to-floor distance.

h' = ceiling-to-work-plane distance (CH_{wp}).

f_1 and f_2 = wall and floor interflectance factors.[4,5,6,7] For f_2, 1.0 is subtracted from the tabulated value.

Effect of Suspension on Utilization

The previous paper dealt with individual comparisons in small rooms between measurement and calculation for selected conditions of room and luminaire variables. Various suspension conditions were used, but the effects of this variable were not separated. For the present paper, however, Table I for large rooms was organized with this in mind. It includes two groups of data each of which contains comparisons at three different suspension distances for a single set of room ratio and luminaire conditions. To preserve a constant luminaire-to-work-plane distance, suspension was changed by varying ceiling distance above the fixed luminaires.

TABLE I.—Measured and Calculated Utilization Factors — Direct—Wide Distribution.
Test units: Sixteen 14" RLM Domes with 150-watt inside-frosted lamps.
Reflectance values: Ceiling, 0.83; walls, 0.52; floor, 0.29.

Room Ratio	2.5(D)	2.5(D)	2.5(D)	5.0(A)	5.0(A)	5.0(A)
Work-plane Height	24"	24"	24"	15"	15"	15"
Unit Suspension	2"	18"	36"	2"	9"	18"
h_c***	.3723	.3167	.3667	.1472	.1667	.1917
h'/h***	.7551	.7895	.8182	.7179	.7500	.7826
Direct Ratio*	.750	.750	.750	.905	.905	.905
Floor Ratio*	.660	.660	.660	.877**	.877**	.877**
f_1***	.4011	.3857	.3683	.4759	.4684	.4576
f_2***	.1786	.1631	.1481	.2304	.2206	.2087
Calculated U.F.****	1.001	0.980	0.960	1.170	1.155	1.140
Measured U.F.	1.017	0.990	0.970	1.159	1.141	1.130

*Fractions of unit output directly incident on work-plane and floor, calculated for conditions of the test.
**Fraction of unit output on floor — estimated from table of relationship of Floor Ratio to Direct Ratio. (Appendix).
***For the exact conditions of the test rooms.
****Effective wall ratio taken as (1.0 — Direct Ratio) h/h'.

The comparisons range from a suspension approaching the ceiling-mounted condition to a suspension of ⅓ the ceiling-to-work-plane distance.[8] Agreement appears to be equally close at all suspensions. This indicates that the Utilization Factor equation given above handles the ceiling-mounted and suspended (within the normal range) conditions with comparable accuracy.

These same comparisons are shown in Table II on a relative basis along with two comparisons from small room tests. Relative utilization factors agree well except in the case of RLM Domes in a 1.0 (H) room where the difference in suspension was extreme (from 20 to 96 inches with MH_{wp} = 75 inches). Here the agreement is less favorable — the calculated value for the 96-inch suspension is about 4 per cent lower than the corresponding measured value. However, the direction of the difference is still logical — the higher measured value can well result from the fact that the wall-incident flux is confined to the lower part of the wall. In this situation the wall-reflected component of utilization will be higher than for the same flux distributed uniformly from the work-plane to the ceiling.

Further calculations have been made for several suspension conditions with various room proportions and flux distributions. The purpose was to determine whether a simplification of utilization data could be effected by the selection of a single moderate suspension (related, of course, to other room dimensions) to represent the usual range. From this study it appears that this range, from ceiling-mounted to a typical long suspension (about ¼ CH_{wp}), could be represented by a suspension of $^1/_7$ CH_{wp} (for example, 15 inches suspension in a room 135 inches high). In the great majority of cases this selection would result in deviations of no

TABLE II.—Relative Utilization Factors as Affected by Different Suspension Distances (Ceiling-to-Units) at Specified Room Ratios.
(For square rooms. Reflectances — Ceiling, 0.80; Walls, 0.50; Floor, 0.30 for filament RLM Dome units and 0.14 for filament R-52.)

Room Ratio	1.0 (H)		1.0 (H)		2.5 (D)			5.0 (A)		
Room Width	12.5′		12.5′		30.0′			30.0′		
Type Unit	R-52		RLM Dome		RLM Dome			RLM Dome		
Number of Units	4		4		16			16		
Suspension	12″	30″	20″	96″	2″	18″	36″	2″	9″	18″
Relative Calculated U.F.*	1.000	0.979	1.000	0.902	1.000	0.979	0.960	1.000	0.987	0.975
Relative Measured U.F.	1.000	0.985	1.000	0.943	1.000	0.973	0.954	1.000	0.985	0.975

*Effective wall ratio taken as (1.0 − Direct Ratio) h/h'.

The relative utilization factors should not be compared as between different test set-ups. Unity values may represent slightly different absolute values as between calculated and measured for each condition.

more than plus or minus 5 per cent for ceiling-mounted and long suspensions respectively. The larger differences are found with wide distributions in high narrow rooms with high reflectances.

Extended (Fluorescent) Sources

No treatment of the subject of utilization today is complete if it does not deal with luminaires far larger in size than the typical filament-lamp luminaire. The size and character of fluorescent luminaires makes careful design very important; many are built into structures making revision of an unsatisfactory installation either costly or impracticable. The obvious fact that these luminaires are not "point" sources has been frequently emphasized. Particularly they may not be regarded as such at the relatively short luminaire-to-work-plane distances common in interior lighting — nor at longer distances when the source is a continuous row of such units. If they are not "point" sources within the usual limits of the term, inverse square calculations should not be used.

The authors believe that there is a feasible mathematical approach to the problem of extended sources. This uses typical photometric information and is capable of dealing with a large number of conditions. The attack is similar to that used by the mathematical analyst in dealing with an extensive source — consider it broken up into sufficiently small elements for which the inverse square law is valid, calculate for each element separately, then sum the results. For example, consider an installation consisting of rows of fluorescent luminaires extending wall-to-wall, and emitting lighting downward. If units were one foot wide, one could assume a row to consist of contiguous 12 x 12-foot elements, each of which has the same shape of flux distribution as the actual individual luminaire which may consist of four or more such elements. Then calculations based upon these small elements may be made. Of course, the end 12-inch element contiguous to an "end" wall will have lower actual output than the average, but this is largely balanced by similar elements farther removed from the wall. The assumption of uniform output of elements makes calculations if anything slightly conservative. Substantial asymmetry of distribution may require further study.

Based on the concept of separate elements, point-by-point or zonal multiplier calculations of lumens delivered to work-plane or other surface may be made. The authors accordingly developed zonal multipliers for certain selected points along the center lines of parallel rows of fluorescent units extending wall-to-wall. Such zonal multipliers for three situations are shown in Tables X, XI, and XII (Appendix). The zonal multipliers from Table X apply for four rows 7.5 feet on centers and 7.5 feet above the work-plane in a room 30 feet square. A satisfactory procedure for obtaining direct ratio (fraction of luminaire output directly incident on work-plane) is illustrated in Fig. 2.

Measurements of direct ratio in the corresponding actual rooms were readily made with the flexible laboratory facilities and highly corrected test cells. Four-foot fluorescent luminaires were used, each having a carefully measured output of 1990 lumens in operating position. These luminaires were of the four-lamp type having white spacers of diamond cross-section between the lamps, but only the two outer lamps were used. The top of the unit was covered to eliminate upward output; its average candlepower distribution is only slightly narrower than a cosine distribution. Since direct ratio excludes inter-reflected light, room reflectance values were kept as low as possible; ceiling reflectance was 0.09 and floor reflectance 0.08. To further reduce reflections, the wall surfaces were removed. Comparison between measured and calculated direct ratios for three patterns of fluorescent luminaires are shown in Table III. The excellent agreement indicates that the zonal method may be adapted to the calculation of direct ratio for continuous rows.

Tables of zonal multipliers, applicable to all use-

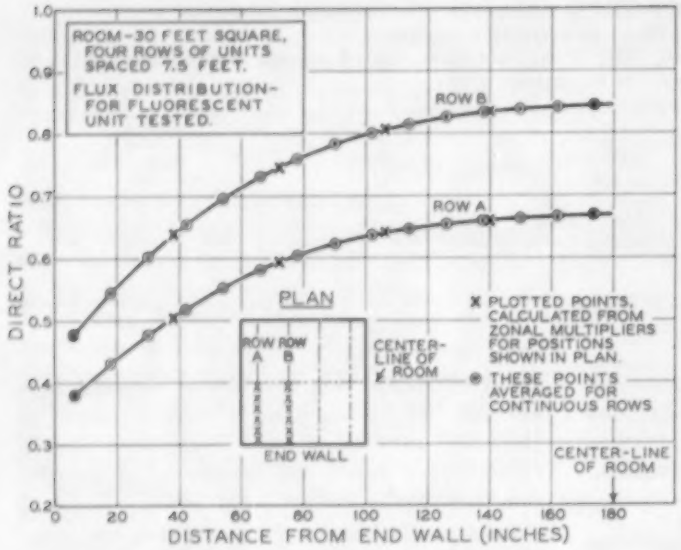


Figure 2. Illustrating procedure for obtaining direct ratio for rows of fluorescent units. Points X, representing direct ratios, were calculated from zonal multipliers from Table X (Appendix) for six locations along each row of units. They establish the curves. Usual photometric data were used. Direct ratio for the entire fluorescent system is the average of ratios for a number of evenly spaced locations.

ful patterns of fluorescent luminaires, could of course be constructed. But it seemed worthwhile to investigate the possibility that some zonal multipliers for individual units could express the performance of the extended source patterns with a sufficient degree of accuracy. The comparison between calculated values of direct ratio for three mathematically-expressed distributions in several patterns and for two room ratios are presented in Table IV. The differences between individual and continuous rows at the same spacing are generally small. As expected, the direct ratio values of the continuous rows of cosine distribution fall between the values for individual luminaires and those for continuous wall-to-wall luminous elements ($S/MH_{wp} = 0.0$). These results indicate that direct ratios for many patterns of continuous-row fluorescent systems can be calculated using the zonal multipliers for $S/MH_{wp} = 0.4$.

TABLE III.—Direct Ratios as Calculated and Measured for Continuous Rows of Direct Fluorescent Units.

Room Ratio	0.6	0.6	2.0		
Room Width*	12'6"	12'6"	30'		
Mounting Height$_{wp}$	10'5"	10'5"	7'6"		
Number of Rows	2	3	4		
Spacing of Rows	6'3"	4'2"	7'6"		
			Inner Rows	Outer Rows	Average
From Calculations	0.264	0.262	0.736	0.583	0.660
From Measurements	0.258	0.257	0.731	0.573	0.652
Per Cent Diff.**	2.3	1.9	0.6	1.7	1.2

Calculations employed zonal multipliers given in Appendix.
Measurements were made with walls removed in large black laboratory space; ceiling reflectance 0.09, floor reflectance 0.08.
*Square rooms (width and length are equal).
**Difference between measured and calculated values in per cent of the former.

TABLE IV.—Direct Ratios for Various Arrangements of Luminaires Calculated for Three Mathematical Distributions and Two Room Ratios.

Luminaire Arrangements	S/MH_{wp}	Constant Candlepower	Cosine	Cosine^3
Room Ratio 0.6 (J)				
2 Rows (Cont.)*	0.6	.148 .146	.162 .257	.422 .410
9 Units 3 Rows (Cont.)*	0.4	.146 .145	.255 .253	.409 .404
Complete Ceil. Square Room**	0.0		.251	
Room Ratio 2.0 (E)				
16 Units 4 Rows (Cont.)*	1.0	.457 .451	.651 .640	.804 .788
100 Units	0.4	.446	.632	.776
Complete Ceil. Square Room**	0.0		.632	

Values for individual luminaires and rows of units calculated with zonal multipliers for 5-degree zones.
*For convenience, zonal multipliers for rows of units are tabulated in Appendix.
**From Reference 14.

Flux Ratio

It is evident that zonal multipliers are useful in determining the fraction of luminaire or system output which reaches the work-plane or other surfaces in a non-reflecting room. But their use entails additional calculation time as compared with the Harrison-Anderson procedure.[9]

We have suggested that the concept of flux ratio as a single number describing luminaire flux concentration has positive values: (1) it can help conserve time for the construction of coefficient tables,

and (2) it helps to present clearly the relationship between different distributions.

In a previous discussion of this subject, the authors presented a suggestion for a new form of flux ratio. This differed substantially from that used by Harrison and Anderson: (1) the calculations connected with horizontal component were eliminated; (2) the flux ratio value for the downward component was the sum of five fractions of 0° - 90° output, each multiplied by a specified weight.

The authors have studied the effect of various patterns of weighting factors for a variety of flux distributions. As a result, another flux ratio based on the following weights is suggested:[10]

Zone	Weight
0° - 10°	1.00
10° - 20°	0.83
20° - 30°	0.65
30° - 40°	0.50
40° - 50°	0.33
50° - 60°	0.16

To determine flux ratio for the downward component of output, multiply the fraction of 0° - 90° output in each zone by its respective weight and add. For example, here is a typical calculation for the downward component of a direct-indirect luminaire:

Fraction of 0° - 90° Output		Weight		Product
.047	×	1.00	=	.047
.136	×	0.83	=	.113
.202	×	0.65	=	.131
.232	×	0.50	=	.116
.182	×	0.33	=	.060
.103	×	0.16	=	.016
		Flux Ratio	=	.483

Fig. 3 illustrates the performance of this type of flux ratio. The plotted points in Chart 3a represent carefully calculated *direct ratios* for distributions which range in concentration from constant candlepower to a very narrow type representing a concentrated-beam downlight. For clarity, direct ratios for only six values of room ratio are included. Chart 3a is based upon a spacing-to-mounting-height ratio of 0.4, while Chart 3b shows the form of curves for a spacing ratio of 1.0. From these charts, this flux ratio appears to give an even better measure of concentration than that explored

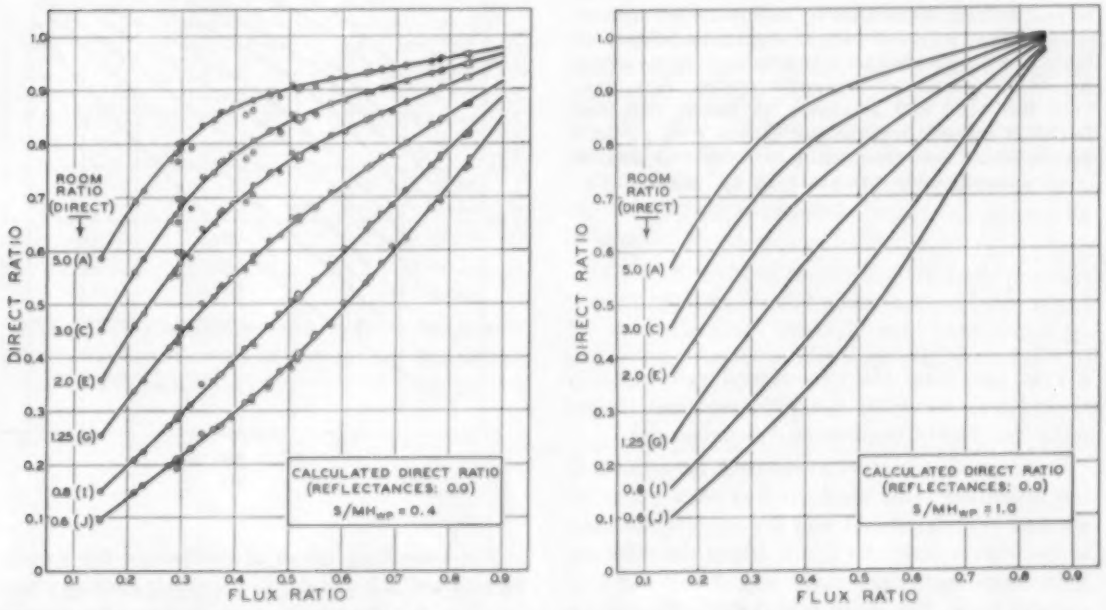
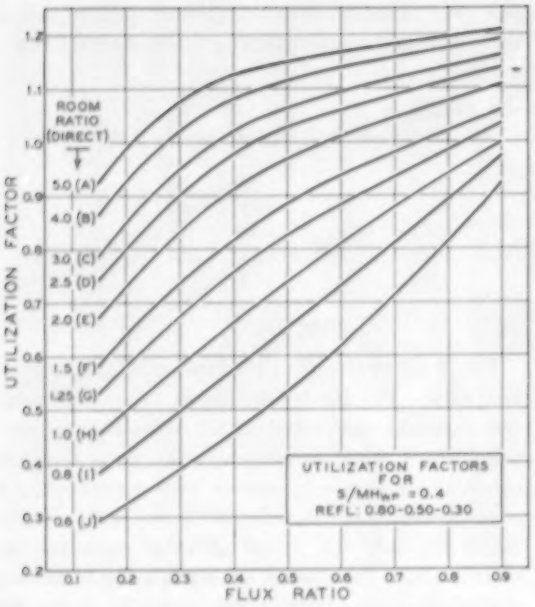
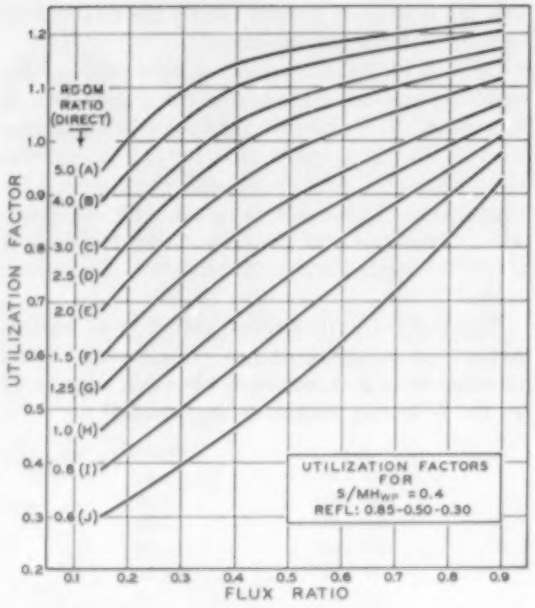


Figure 3. Charts of direct ratio plotted against a proposed flux ratio, for several room proportions as indicated by curves. Chart 3a (left) is calculated for a spacing-to-mounting-height (S/MH_{cp}) ratio of 0.4; the plotted points, representing a wide variety of downward distributions, fall quite well into curve form. Chart 3b (right) shows similar curves for S/MH_{cp} = 1.0. The proposed flux ratio (index of concentration) used as abscissa represents the fractions of downward output in certain 10-degree zones multiplied by the following weights and added:

Zone	Weight
0° - 10°	1.00
10° - 20°	0.83
20° - 30°	0.65
30° - 40°	0.50
40° - 50°	0.33
50° - 60°	0.16





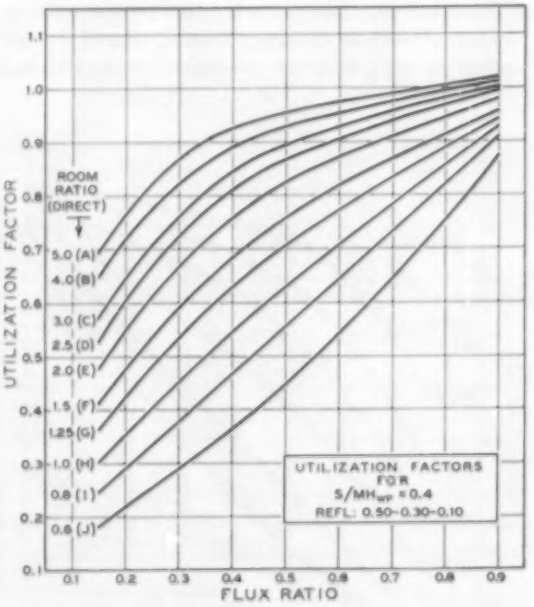


Figure 4. Specimen Flux-Ratio — Utilization Factor Charts. Charts 4a, 4b and 4c apply for the same conditions except reflectances; similar charts may be drawn for each combination of spacing ratio and room reflectance. To find Utilization Factors, determine Flux Ratio, use it as the abscissa, read value from each Room Ratio curve. Multiply Utilization by Downward Efficiency to obtain Downward Coefficient of Utilization. Charts are based on zonal-interflection calculations, using the utilization factor equation of a previous section. Basis, room 11.25 feet high, unit suspension 15 inches, work-plane height 30 inches. Interflectance factors from published tables. Direct ratio from Figure 3a; floor ratio obtained from relationship given in Table IX (Appendix).

a year ago, since the curves tend more directly toward zero for wider concentrations and toward unity for highly concentrated distributions.

Such graphs can serve as the basis for a calculating procedure. One finds the flux ratio value for the unit considered and uses the appropriate chart to find direct ratio. To this is added the reflected-light component, which is the sum of wall and floor contributions. This is the sum of the last two terms of the equation:

$$\text{Utilization Factor} = \text{Direct Ratio} + (1.0 - \text{Direct Ratio})\frac{h}{h'}f_1 + (\text{Floor Ratio})\,f_3$$

It can be individually calculated or derived from pre-calculated charts.

For compiling tables of coefficients for specific luminaires, it is simpler to use charts such as shown in Fig. 4. Here *utilization factor* (direct ratio plus inter-reflected components) is plotted against flux ratio. The procedure for constructing a table of coefficients for a downward component of output is as follows:

1. Determine the flux ratio of the downward component of output.
2. From charts (such as Fig. 4) find utilization

factor for each room ratio, and reflectance combination — at the spacing ratio desired.

3. To obtain Downward Coefficients of Utilization, multiply all utilization factors by the constant downward efficiency of the unit (Downward efficiency $= \frac{0° - 90° \text{ luminaire output}}{\text{total output of lamps}}$).

Note that Fig. 4a is for one reflectance combination (0.85 - 0.50 - 0.30) at one spacing-to-mounting-height ratio only. Other such pre-calculated charts can be readily constructed; Figs. 4b and 4c are similar charts for different reflectance patterns, 0.80 - 0.50 - 0.30 and 0.50 - 0.30 - 0.10 respectively. These charts are based on a nominal suspension distance of 15 inches in rooms 135 inches high.

As an example of their application, assume a luminaire with downward output (0° - 90°) of say 1450 lumens with a flux ratio calculated at 0.483. Total lamp lumens are 2000 so that Downward Efficiency is 0.725. Units are to be used on spacing ratio 0.4, in rooms with reflectances of 0.80 - 0.50 - 0.30. For each room ratio, find from Fig. 4b the utilization indicated by the curves for flux ratio 0.483 and multiply each value by 0.725:

(1) Room Ratio	(2) Utilization Factor (From Fig. 4b, at flux ratio = 0.483)	(3) Coefficient of Utilization (0.725 × Col. 2) for 0.80 - 0.50 - 0.30 and $S/MH_{wp} = 0.4$
0.6 (J)	0.515	0.373
0.8 (I)	0.640	0.464
1.0 (H)	0.725	0.525
1.25 (G)	0.810	0.587
1.5 (F)	0.870	0.630
2.0 (E)	0.960	0.696
2.5 (D)	1.020	0.740
3.0 (C)	1.055	0.765
4.0 (B)	1.110	0.805
5.0 (A)	1.145	0.830

Should the luminaire have both upward and downward components, add the upward and downward coefficients for the proper room ratios[11] to obtain the over-all Coefficient of Utilization. Coefficients for upward output are discussed separately below.

Indirect Lighting and Upward Components

Filament — Wide Distribution

The authors reported in 1953 the results of measurements of utilization factor for upwardly-directed light in relatively small rooms with a wide range of reflectance combinations (Table VI of the previous paper). The principal flux distribution employed was a wide bat-wing, characteristic of a silvered-bowl lamp with simple shielding designed to obstruct as little light returned from the ceiling as possible. However, room ratio was limited — the largest used for tests was 1.5 (F), but curves were extrapolated to 2.0 (E).

These measurements have been continued with the same type of luminaire in laboratory test rooms 30 feet square. This size allowed the use of full-scale rooms in the neighborhood of ratios 2.0 (E) and 2.5 (D). At the other extreme test rooms up to 5.0 (A) were found practicable at a scale not under one-half full size. The same luminaire spacing-to-suspension ratio (3.0 - 3.25) was used as in the small-room series, giving due consideration to a practical number of units. Patterns comprising sixteen units were chosen for full-scale tests at room ratio 2.3, and sixty-four units for room ratio 5.0 (A). To avoid undue obstruction of the ceiling the actual tests were made with no more than 16 units at any one time — results for different patterns were weighted and averaged. Cross-sections of selected rooms appear in Fig. 5.

In Fig. 6 we have combined data from previous tests in small rooms and recent tests in large rooms for two reflectance combinations. They fitted together quite well. For comparison, the chart in-

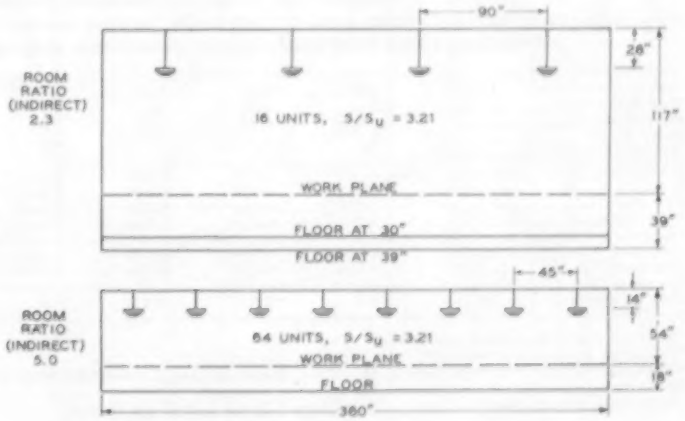


Figure 5. Cross-sections of two of the 30 x 30-foot rooms used for silvered-bowl indirect lighting tests with various numbers of units and suspension distances.

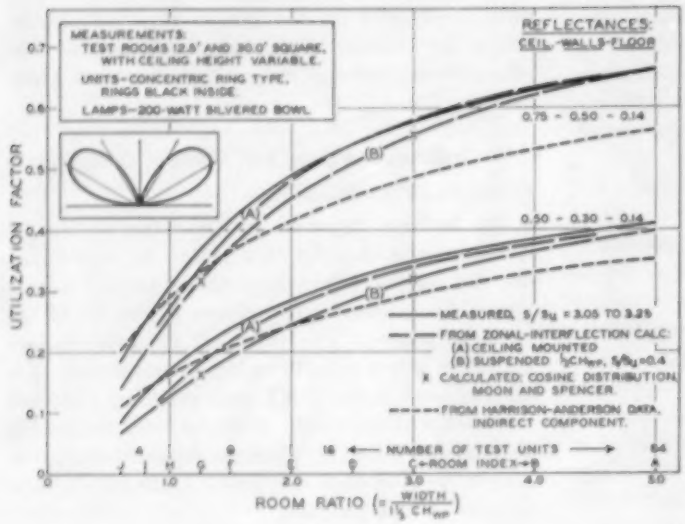


Figure 6. Measured utilization factors for two combinations of ceiling, wall and floor reflectance and for spacing-to-suspension ratio of 3.05 to 3.25 are given in the solid curves. Other curves are derived from two sets of published utilization data. Note that they are based on other conditions as to suspension and number of units. Values indicated by X are for an indirect cosine distribution co-extensive with the ceiling as calculated for room ratios at which our test rooms were 10 feet high. Calculated utilization factors do not include an allowance for obstruction of ceiling-reflected light.

cludes values from three systems of published data:

1. Harrison-Anderson tables based on measurements.[9]
2. Zonal multiplier-interflection calculations[12] for luminaires in ceiling mounted and suspended conditions.
3. From calculations which assume a cosine distribution directed upward and wall-to-wall extent of luminaire. Interflection data are employed in deriving utilization factor.[13]

The various assumptions as to flux distribution, luminaire suspension, number and pattern of units, etc., make precise evaluation of these data difficult. The general trend, however, shows that calculated values for these small luminaires are relatively low in high narrow rooms, but tend to converge with our measured values in larger rooms.

We have also made a series of comparisons between measured values and those calculated as carefully as possible for the exact conditions of the test rooms. To determine ceiling ratio (fraction of luminaire output directly incident on ceiling surface), zonal multipliers by 5° zones were calculated for the exact arrangements and suspension distances of the luminaires. Wall ratio is of course ceiling ratio subtracted from unity. Interflectance factors were obtained from published tables; room set-ups for this comparison were selected to have the same relationship of ceiling and work-plane heights as assumed in the tables. Some of these exact comparisons are found in Table V. As expected, the differences between measurement and calculation are smaller than found previously in small high rooms where the effects of mathematical approximations and of variations in ceiling brightness distribution are greater. The measured values are all higher than the calculated values in spite of the fact that tests in actual rooms involve some

TABLE V.—Measured and Calculated Utilization Factors — Silvered Bowl Indirect.
(Test units: three concentric rings, finished black inside. Spacing-to-suspension ratio, 3.21. Square room, width = 30'. Work-plane height ¼ of ceiling height. Calculations based on exact test room conditions.)

Ceiling Reflectan e	0.80	0.80	0.80	0.70	0.50	0.50	0.50	0.30
Wall Reflectance	0.50	0.50	0.50	0.50	0.50	0.30	0.10	0.50
Floor Reflectance	0.30	0.30	0.30	0.10	0.30	0.30	0.30	0.10
Room Ratio*	2.3	5.0	5.0	4.0	5.0	5.0	4.0	3.0
Number of Units	16	64**	16	64**	16	16	16	16
Ceiling Ratio***	0.840	0.913	0.840	0.913	0.840	0.840	0.840	0.840
k_z	0.433	0.200	0.200	0.250	0.200	0.200	0.250	0.333
"f_w" (wall)†	0.317	0.254	0.254	0.315	0.311	0.173	0.050	0.222
"f_c" (ceiling)†	0.613	0.804	0.804	0.592	0.464	0.435	0.375	0.219
Calculated U.F.	0.566	0.765	0.732	0.568	0.440	0.393	0.323	0.220
Measured U.F.	0.592	0.783	0.776	0.574	0.473	0.425	0.353	0.243
Diff. in per cent††	4.3	2.3	5.7	1.0	7.0	7.5	8.5	9.5

*Harrison-Anderson indirect room ratio.
**Weighted average of three tests.
***Fraction of output directly incident on ceiling. Based on special zonal multipliers for 5-degree zones, derived graphically.
†From published tables cross-plotted for the k_z values desired.
††Difference between measured and calculated factors in per cent of the former.

obstruction of the ceiling and an initial wall brightness distribution which is less favorable than the uniformity assumed by the calculations. Differences are somewhat larger at lower ceiling and wall reflectances.

Numerous measurements of utilization factor with this wide bat-wing upward distribution have been made in rooms of different reflectances and proportions. These data are summarized in Table VI A in a form suitable for ready use. To obtain Upward Coefficient of Utilization for this distribution and condition of obstruction, simply multiply the desired utilization factors from the table by the upward efficiency of the unit (Upward efficiency $= \frac{90° - 180° \text{ luminaire output}}{\text{total output of lamps}}$). For example, the Upward Coefficient for a room ratio of 1.5 (F) with reflectances 0.70 - 0.30 - 0.30 is:

Utilization Factor = .340
Upward Efficiency (assumed) = .82
Product is Upward Coefficient of Utilization = .279
This procedure is even simpler than that heretofore used; no subtraction of a horizontal component is required.

The data summarized in Table VI A are for specific numbers of units and a given spacing-to-suspension ratio. In installations the suspension distances often vary over a considerable range. To determine the effect of this on utilization a number of tests have been made in the laboratory. The curves marked "A" in Fig. 7 show there is little change in utilization as suspension distance is varied. Similar data for smaller rooms were shown in Fig. 11 of our last paper.[2] Shortening a long suspension generally increases utilization somewhat, since more light is directed to favorable locations on the ceiling, but a point is reached where the luminaire obstructs and traps a sufficient amount of its own light reflected by the ceiling to cause a net reduction. This is the case with very short suspensions.

Many indirect installations have a white strip around the top of the wall where some part of luminaire output is directly incident. The discussion and tables above, in common with other systems of utilization data, assume uniform wall *reflectance*. Measurements in the 30-foot square test room were made with the 0.80 ceiling reflectance extended down the wall 24 inches. Silvered-bowl units were employed at a suspension of 28 inches. Reflectance of the lower wall was 0.50. Compared with uniform walls of 0.50 reflectance, this special pattern increased the utilization factor up to 7 per cent. Measurements in low ratio rooms, with a 12-inch white strip, gave gains as high as 10 per cent.

With respect to variations of initial surface *brightness*, some idea is afforded by a mathematical study of the effect of having the light concentrated near the ceiling rather than uniformly distributed over the wall. For the study, the case chosen was the room (indirect room ratio 0.75) shown in cross-section, with luminaires, in Fig. 9 of our 1953 paper.[2] Reflectances of 0.80 - 0.50 - 0.14 were selected. The ceiling ratio was 0.746; wall ratio 0.254. Light represented by the latter fraction was actually concentrated at the top of the wall within a strip about 12 inches wide. For our calculation it was assumed to be a strip of the same width uniformly lighted. This strip on all four walls was treated as a surface source; the proper flux transfer equation[14] was used to determine the flux de-

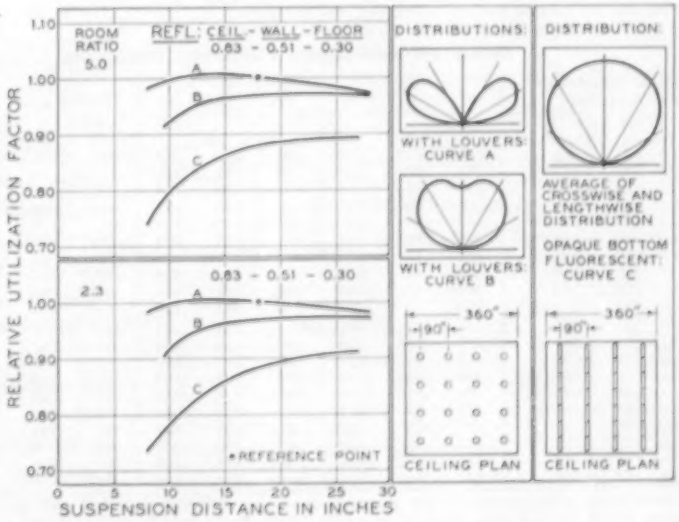


Figure 7. Examples of the effect of varying suspension distance for a fixed spacing of indirect luminaires. Ceiling height of room is also fixed — units are raised and lowered in room of constant room ratio. Curve A applies for the silvered-bowl unit with 14-inch diameter open concentric ring louver (black finish on inside surface of louvers). Curve B shows the effect of a narrower distribution with the same obstruction. For this purpose a 6½-inch cylinder with diffusing glass cover plate was used with the same concentric ring louver attached. Curve C shows the effect of trapping and obstruction from rows of totally indirect fluorescent units that are opaque and 12 inches wide. The distribution is approximately the same as B.

TABLE VI.—Utilization Factors for Indirect Components.

A. Wide Distribution Silvered Bowl Luminaires, Spacing-to-Suspension Ratio 3.05-3.25*

Ceiling Reflectance**				.80			.70			.50			.30			.10	
Wall Reflectance				.50	.30	.10	.50	.30	.10	.50	.30	.10	.50	.30	.10	.50	.30	.10
Present†		Proposed† Room Ratio																
0.6	(J)	0.800		.199	.146	.093	.171	.126	.081	.114	.086	.058	.075	.056	.037	.037	.025	.011
0.8	(I)	1.067		.265	.207	.149	.232	.182	.132	.166	.133	.099	.108	.082	.057	.049	.034	.019
1.0	(H)	1.333		.325	.262	.201	.286	.231	.178	.207	.170	.132	.132	.104	.077	.059	.043	.026
1.25	(G)	1.667	Floor Refl. .10	.384	.320	.257	.338	.282	.227	.246	.206	.166	.156	.127	.097	.069	.051	.035
1.5	(F)	2.000		.433	.367	.306	.380	.324	.269	.277	.236	.195	.176	.147	.118	.076	.059	.043
2.0	(E)	2.667		.508	.443	.380	.447	.387	.333	.326	.282	.242	.205	.178	.153	.085	.070	.056
2.5	(D)	3.333		.560	.494	.436	.493	.434	.383	.359	.318	.278	.229	.202	.178	.091	.078	.065
3.0	(C)	4.000		.600	.537	.482	.528	.472	.422	.384	.344	.305	.247	.220	.197	.095	.083	.070
4.0	(B)	5.333		.653	.596	.545	.573	.523	.475	.416	.380	.344	.268	.242	.223	.100	.089	.077
5.0	(A)	6.667		.690	.638	.591	.602	.558	.514	.437	.405	.371	.279	.255	.238	.102	.093	.082
0.6	(J)	0.800		.209	.151	.094	.179	.130	.082	.118	.089	.059	.077	.057	.037	.038	.025	.011
0.8	(I)	1.067		.278	.214	.151	.243	.188	.134	.173	.137	.101	.111	.084	.058	.050	.034	.019
1.0	(H)	1.333		.340	.271	.204	.298	.230	.181	.215	.174	.134	.135	.106	.078	.060	.043	.026
1.25	(G)	1.667	Floor Refl. .30	.403	.332	.262	.354	.293	.231	.255	.212	.169	.159	.129	.099	.070	.051	.035
1.5	(F)	2.000		.458	.385	.313	.401	.340	.276	.289	.245	.199	.180	.150	.121	.077	.059	.043
2.0	(E)	2.667		.544	.467	.392	.479	.409	.343	.344	.291	.248	.211	.183	.157	.086	.071	.056
2.5	(D)	3.333		.610	.529	.453	.534	.463	.398	.383	.327	.283	.236	.209	.182	.092	.079	.065
3.0	(C)	4.000		.661	.578	.505	.576	.505	.444	.412	.356	.313	.255	.228	.203	.096	.084	.071
4.0	(B)	5.333		.733	.651	.584	.634	.567	.510	.450	.398	.355	.279	.252	.229	.101	.090	.078
5.0	(A)	6.667		.783	.703	.642	.673	.611	.558	.474	.428	.387	.294	.268	.248	.104	.094	.083

*Table based on measurements with 4 and 9 symmetrically located units in 12½ ft. sq. rooms, and 16 and 64 symmetrically located units in 30 ft. sq. rooms. Room Ratios used in tests: 0.75, 0.90, 1.2, and 1.5 for 12½ ft. sq. rooms; 2.3, 3.0, 4.0 and 5.0 for 30 ft. sq. rooms.

**Note: ceiling reflectances range from 0.80 to 0.10 in Table VI A.

†Room Ratio $= \frac{2\ (\text{width} \times \text{length})}{2\ CH_{wp}\ (\text{width} + \text{length})}$, where CH_{wp} = distance, ceiling to work-plane.

‡Room Ratio $= \frac{2\ (\text{width} \times \text{length})}{H_{wp}\ (\text{width} + \text{length})}$, where H_{wp} = distance, source (primary or secondary) to work-plane; for indirect, ceiling is effective source.

B. Continuous Row Opaque Fluorescent Luminaires, 12-inch Width, 22-inch Suspension*

Ceiling Reflectance**				.85			.80			.70			.50			.30		
Wall Reflectance				.50	.30	.10	.50	.30	.10	.50	.30	.10	.50	.30	.10	.50	.30	.10
Room Ratio Present		Proposed																
0.6	(J)	0.800		.165	.136	.085	.170	.125	.078	.150	.110	.070	.102	.077	.052	.061	.046	.030
0.8	(I)	1.067		.246	.192	.138	.230	.180	.129	.201	.158	.114	.140	.112	.084	.081	.062	.043
1.0	(H)	1.333		.303	.244	.187	.285	.230	.176	.246	.199	.153	.173	.142	.110	.101	.080	.059
1.25	(G)	1.667	Floor Refl. .10	.363	.303	.245	.338	.282	.226	.296	.247	.197	.208	.174	.140	.122	.099	.076
1.5	(F)	2.000		.412	.350	.291	.382	.325	.269	.335	.286	.236	.238	.203	.167	.140	.117	.094
2.0	(E)	2.667		.488	.425	.366	.455	.397	.342	.400	.346	.298	.282	.246	.209	.170	.147	.126
2.5	(D)	3.333		.545	.480	.425	.509	.449	.396	.449	.395	.349	.316	.280	.244	.189	.167	.146
3.0	(C)	4.000		.587	.525	.472	.550	.492	.442	.483	.432	.386	.340	.305	.270	.206	.184	.164
4.0	(B)	5.333		.639	.583	.533	.599	.546	.500	.520	.475	.431	.367	.335	.303	.223	.201	.185
5.0	(A)	6.667		.666	.616	.571	.625	.578	.535	.544	.504	.464	.381	.353	.323	.233	.213	.198
0.6	(J)	0.800		.191	.139	.086	.175	.128	.079	.154	.112	.071	.105	.079	.053	.063	.047	.030
0.8	(I)	1.067		.255	.197	.139	.238	.185	.130	.208	.161	.115	.145	.115	.085	.084	.064	.044
1.0	(H)	1.333		.315	.251	.189	.296	.238	.178	.255	.204	.155	.180	.146	.112	.105	.083	.061
1.25	(G)	1.667	Floor Refl. .30	.380	.313	.246	.353	.293	.229	.309	.255	.200	.218	.180	.143	.127	.103	.079
1.5	(F)	2.000		.433	.363	.295	.401	.338	.273	.352	.296	.240	.250	.210	.171	.147	.123	.099
2.0	(E)	2.667		.519	.445	.372	.484	.416	.350	.425	.363	.304	.300	.254	.215	.180	.156	.133
2.5	(D)	3.333		.585	.507	.434	.546	.474	.406	.482	.418	.359	.339	.290	.251	.200	.177	.155
3.0	(C)	4.000		.636	.556	.486	.596	.521	.455	.524	.459	.404	.369	.319	.280	.221	.198	.176
4.0	(B)	5.333		.704	.625	.560	.660	.586	.526	.578	.512	.461	.404	.357	.319	.241	.218	.198
5.0	(A)	6.667		.743	.667	.610	.697	.626	.572	.607	.551	.504	.425	.384	.347	.254	.232	.215

*Table based on measurements with two continuous rows of units spaced 6¼ feet apart in 12½ ft. sq. rooms (16% of ceiling area obstructed), and four continuous rows of units spaced 7½ feet apart in 30 ft. sq. rooms (13.3% of ceiling area obstructed). Room Ratios used in tests: 0.75, 0.90, 1.2, 1.5, and 2.0 for 12½ ft. sq. rooms; 2.3, 3.0, 4.0, and 5.0 for 30 ft. sq. rooms.

**Note: ceiling reflectances range from 0.85 to 0.30 in Tables VI B and C.

Data are extrapolated for low ceiling and wall reflectances.

C. Continuous Row Opaque Fluorescent Luminaires, 12-inch Width, 8-inch Suspension*

Ceiling Reflectance**				.85			.80			.70			.50			.30		
Wall Reflectance				.50	.30	.10	.50	.30	.10	.50	.30	.10	.50	.30	.10	.50	.30	.10
Room Ratio Present		Proposed																
0.6	(J)	0.800		.156	.114	.072	.144	.106	.067	.135	.092	.058	.081	.061	.041	.052	.038	.026
0.8	(I)	1.067		.208	.162	.117	.193	.151	.108	.167	.131	.095	.109	.088	.065	.068	.052	.036
1.0	(H)	1.333		.256	.206	.158	.238	.193	.147	.207	.168	.128	.135	.110	.086	.082	.065	.048
1.25	(G)	1.667	Floor Refl. .10	.309	.257	.206	.288	.240	.192	.244	.204	.163	.164	.137	.111	.097	.079	.060
1.5	(F)	2.000		.354	.301	.248	.327	.278	.231	.278	.236	.196	.189	.161	.133	.111	.093	.075
2.0	(E)	2.667		.416	.363	.313	.386	.337	.289	.329	.284	.245	.226	.196	.169	.132	.115	.099
2.5	(D)	3.333		.462	.407	.360	.430	.379	.335	.370	.326	.288	.256	.227	.197	.151	.133	.117
3.0	(C)	4.000		.493	.441	.396	.459	.411	.368	.399	.357	.319	.280	.251	.222	.167	.149	.133
4.0	(B)	5.333		.530	.484	.443	.496	.453	.415	.433	.394	.359	.307	.280	.254	.191	.172	.158
5.0	(A)	6.667		.559	.516	.479	.520	.481	.446	.450	.417	.384	.319	.296	.271	.202	.185	.172
0.6	(J)	0.800		.160	.117	.073	.148	.107	.067	.139	.094	.059	.083	.063	.042	.053	.039	.026
0.8	(I)	1.067		.215	.166	.118	.200	.154	.109	.173	.134	.096	.113	.090	.066	.070	.053	.037
1.0	(H)	1.333		.266	.212	.160	.247	.197	.147	.215	.173	.130	.140	.113	.087	.085	.067	.049
1.25	(G)	1.667	Floor Refl. .30	.323	.266	.209	.301	.248	.194	.255	.210	.166	.171	.142	.113	.101	.082	.063
1.5	(F)	2.000		.372	.312	.253	.343	.287	.231	.292	.244	.200	.198	.167	.136	.117	.098	.079
2.0	(E)	2.667		.443	.380	.319	.410	.352	.296	.350	.298	.251	.240	.202	.173	.140	.121	.104
2.5	(D)	3.333		.496	.430	.369	.462	.401	.343	.397	.344	.297	.275	.235	.203	.160	.142	.123
3.0	(C)	4.000		.534	.467	.409	.498	.436	.381	.432	.379	.333	.304	.263	.231	.179	.160	.142
4.0	(B)	5.333		.584	.519	.465	.546	.485	.435	.476	.426	.384	.338	.299	.267	.206	.186	.169
5.0	(A)	6.667		.623	.560	.511	.580	.521	.476	.502	.456	.416	.356	.322	.291	.220	.200	.186

*Table based on measurements with two continuous rows of units spaced 6¼ feet apart in 12½ ft. sq. rooms, and four continuous rows of units spaced 7½ feet apart in 30 ft. sq. rooms. Room Ratios used in tests: 1.5 and 2.0 for 12½ ft. sq. rooms; 2.3, 3.0, 4.0, and 5.0 for 30 ft. sq. rooms.

Data are extrapolated for low ceiling and wall reflectances.

TABLE VII.—Interflectance Factors for Wall and Ceiling of Test Room Lighted with Four Wide Distribution Indirect Luminaires.

	(1) Wall and Ceiling Ratios	(2) f — For Surfaces*	(3) f' — For Test Room	(4) Difference in Per Cent****
Wall	0.254	.1667	.1279**	−23.3
Ceiling	0.746	.2246	.2929***	+30.4

*Uniformly bright, diffusing surfaces.
**Based on flux transfer and interflection equations.
***Derived from f'_1 and measured utilization factor of 0.351.
****Difference in per cent of factor for uniformly bright surfaces.

livered from this strip to each of the other room surfaces including the work-plane. Then f-factors from the interflectance equations were employed to find how much more illumination was contributed to the work-plane by the second and subsequent reflections. This resulted in a new interflectance factor (f'_1) for this particular pattern of wall brightness, shown in Column (3), Table VII. It is about 23 per cent lower than the value for a uniformly bright wall in this room (Column 2).

To find an f_2-factor applicable for a ceiling of the brightness distribution found in the test room (about 3:1), the f'_1 value together with ceiling and wall ratio and the measured utilization factor can be used in the following equation.

$$\text{Utilization Factor} = (\text{Wall Ratio})\ f'_1 + (\text{Ceiling Ratio})\ f'_2$$

The value of f_2 obtained by this procedure is about 30 per cent higher than the f-value for a uniformly bright diffusing ceiling.

Filament — Narrow Distribution

The degree of concentration of flux distribution is an important factor in determining the proportions of light output directed initially to ceiling and upper walls respectively. For a given pattern of luminaires and suspension distance, a more concentrated (nearly cosine) distribution places a larger fraction of output on the ceiling than a wide distribution. This is shown in Table VIII, which includes ceiling ratios for several room proportions. For our test rooms they were carefully determined with specially calculated zonal multipliers. Included in the table for reference are values calculated from published zonal multipliers[12] which have been proposed for any pattern of luminaires. Note that these values are for the same room proportions but for different conditions of mounting and numbers of units.

However, ceiling ratio and room reflectances are not the only factors affecting utilization. An additional factor is the trapping effect of the actual luminaires. It is of course of greater importance the larger and the more opaque the luminaire, the shorter its suspension, and the narrower its distribution.

To determine the overall effect of an extreme change in distribution, luminaires providing a narrow flux distribution upward were employed for a series of tests. This distribution, shown in the inset of Fig. 7 for curves marked "B," was obtained with white metal cylinder units, 6½" diameter, with diffusing glass cover plates. These covers were carefully selected for uniform transmission and diffusion. Construction permitted attachment of the three-concentric ring louver of the silvered-bowl luminaire for equivalent obstruction of the ceiling. For minimum interference of upward flux, the units were suspended by three small wires attached to a metal ring; units were photometered with wires and ring in place.

Some results and comparisons for room ratios 2.3 and 5.0 (A) may be obtained from Fig. 7. These charts afford a direct comparison, for equal ceiling obstruction (Curves A and B), between the silvered-bowl and the narrower distribution. Sixteen units were used in 30-foot square test rooms. At long suspensions the differences are very small. In this region for high reflectances and large rooms, the utilization factors of Table VI A might be satisfactory. However, at short suspensions, the difference due to greater trapping is appreciable. Tests at lower room ratios would be expected to produce greater difference in utilization for these two filament flux distributions.

Fluorescent — Extended Sources

Fluorescent lighting systems vary widely in many respects which have an effect on utilization data. Besides distribution and various conditions

TABLE VIII.—Ceiling Ratios As Calculated for Specific Test Rooms.

Room Ratio*	Number Units	Susp.	S/Su**	Calculated For Test Room Conditions***	Calculated from Published Zonal Multiplier Ceil. Mtd.	Data Su = ½ CH_{mp}
Wide Batwing Distribution						
0.75	4	23″	3.25	0.746	0.81	0.422
1.5	9	16½″	3.05	0.807	0.90	0.647
2.3	16	28″	3.21	0.840	0.94	0.739
5.0	64	14″	3.21	0.913	0.99	0.890
Narrow Upward Distribution						
0.75	4	23″	3.25	0.886	0.81	0.624
1.5	9	16½″	3.05	0.928	0.90	0.781
2.3	16	28″	3.21	0.938	0.94	0.854
5.0	64	14″	3.21	0.967	0.99	0.946

*Harrison-Anderson indirect room ratio.
**Spacing-to-Suspension ratio.
***Calculated by 5″ zonal multipliers established for the specific conditions.

of mounting, other factors are important — the pattern, sizes, and light-trapping effects.

Accordingly, our studies have included measurements of utilization for simple patterns of extended sources in both small and large rooms. For this purpose a unit having only upward output of roughly cosine distribution (see inset of Fig. 7 for curves marked "C") was selected. It was a thin-section luminaire, 12 inches wide, for four 40-watt T-12 lamps. For our purposes the unit was modified by covering the under side with black cloth to eliminate downward light. The black in turn was covered with white cloth to minimize absorption of room-reflected light by the units. With respect to the trapping of ceiling-reflected light, this condition of maximum opacity was somewhat compensated for by the use of the outer pair of lamps only in a relatively narrow unit. These variables in the design and structure of lighting equipment are believed important in this respect; an extensive investigation would be needed to evaluate fully their effects on utilization.

Many tests with different reflectances, room ratios and suspension distances have been made with the laboratory unit described above. Of these, certain series are of particular interest in connection with the amount of ceiling surface obscured by the luminaires, and with the trapping of light reflected by the ceiling. The first was conducted in the 12½-foot-square rooms, with reflectances of 0.825 - 0.50 - 0.30. Two rows of the units were used at a time in two locations with and without simulated units of the same width in each case. Without these simulated units 16 per cent of the ceiling was obscured; with, 32 per cent. In this series the suspension distance was changed by increasing the ceiling height, keeping the luminaires fixed with respect to the work-plane. This caused room ratio to vary over a range from 0.8 to 1.13 for different suspension distances. Measured results are shown in Fig. 8, together with the results of calculation by two methods. This figure shows that at long suspensions any increase in utilization due to non-uniform ceiling brightness is almost cancelled by the obstruction effect of units covering 16 per cent of the ceiling. For greater obstruction, for example 32 per cent, the net utilization is much lower. At extremely short suspensions both curves show substantial reductions. This is caused by additional trapping of ceiling-reflected light. For example, at an 8-inch suspension distance (room ratio 1.1) tests show 22 and 26 per cent lower values than obtained by calculation.

Another series was tested in the 30-foot square rooms, with approximately the same reflectance combination. In this case two room ratio values were chosen; ceiling height was fixed for each and luminaires were suspended at different distances. Fig. 7 shows the relative utilization obtained with the three upward distributions (A, silvered bowl; B, diffuse filament unit with louvers and obstruction like A; C, fluorescent with additional obstruction). As shown, A and B were used in a 16-unit pattern, C in four continuous rows of 7 units each. The curves show clearly the substantial reduction in utilization factor due to the additional trapping effect of the large size units and continuous rows. Naturally it is at a maximum with the short suspensions.

These exploratory measurements emphasized the

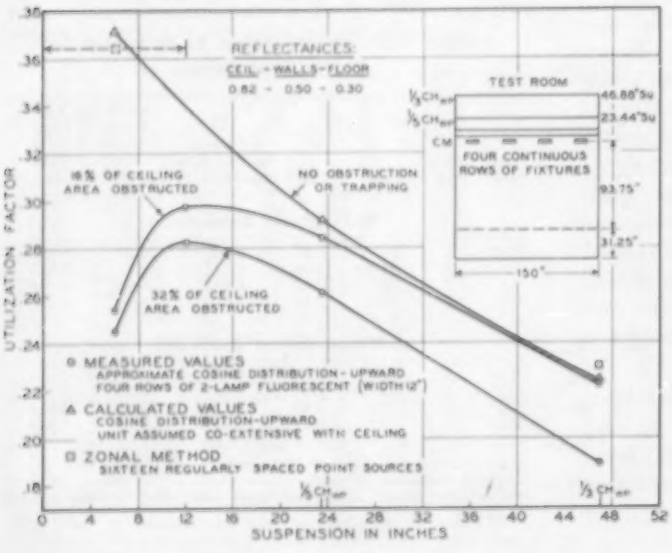


Figure 8. Example of the effect of ceiling obstruction and trapping at different suspension distances. Units are at a fixed height above the work-plane, and the ceiling is raised above them to effect an increase in luminaire suspension. This causes room ratio to change with changes in suspension. Calculated values take no account of obstruction of ceiling area by units or trapping of ceiling-reflected light.

need for additional tables of utilization factors for the upward component from fluorescent luminaires. To this end a series of general tests were conducted. In the small test rooms simple patterns of one, two and three continuous and regularly spaced rows were measured. These rows were 3 units long. In the 30-foot test rooms, four equally spaced rows of 7 units were used. Where more than two rows were required, tests on one or two at a time were made, using simulated units to provide additional obstruction of the ceiling. Then positions of actual and simulated units were interchanged for other tests. Various reflectance combinations and suspension distances were used. Results of these tests have been analyzed and presented in Table VI B & C, which are based on 22- and 8-inch suspension distances, respectively. These tables are readily used to determine upward utilization factor and coefficient in the manner outlined for Table VI A under Filament Indirect — Wide Distribution. In using these data reasonably accurate or at least conservative coefficients will be obtained for units of this width and these suspensions. However, the obstruction effect of other actual units must be appraised. Perhaps additional data will be necessary for upward components such as those for exposed fluorescent lamps, shallow luminous side ceiling-mounted units, and extremely wide shielded units with short suspensions. Those with very little obstruction, such as the first two, might be represented reasonably well by Table VI A for silvered-bowl units.

To present a clear picture of the relationship of these tables to each other and to values from the data of Harrison and Anderson, Fig. 9 is included. Our tabulated data were interpolated for the 14 per cent floor to correspond with the factors taken directly from Reference 9.

The whole problem of upward components and their utilization factors, affected as they are by size, opacity, suspension distance and flux distribution—in short, trapping of light—might be greatly simplified. Each unit and an associated section of reflecting ceiling might be regarded primarily as a direct lighting unit; its downward component would give the combined effect of luminaire, ceiling-reflected light and all losses, including those due to trapping between ceiling and unit. Probably a small upward component would remain, but it should occasion little error when treated conventionally. Appealing as this is, it must be recognized that its use would require a separate photometric test for each combination of ceiling reflectance and suspension distance chosen for utilization tables. Perhaps five ceiling reflectances and two or three suspension distances would suffice ordinarily. Then trapping as well as the effect of temperature on lamp output would be evaluated photometrically.

Obstructions — Other Than Luminaires

Systems of utilization factors, whether derived from laboratory tests or by calculation, are based on empty rooms. Most installations, however, contain architectural elements, furnishings or equipment which reduce the amount of light reaching the work-plane; people in the space may do the same. Obstructions situated entirely below the work-plane affect inter-reflected light only and can be handled reasonably well through correction of floor reflectance. On the other hand, obstructions above the work-plane must be given greater con-

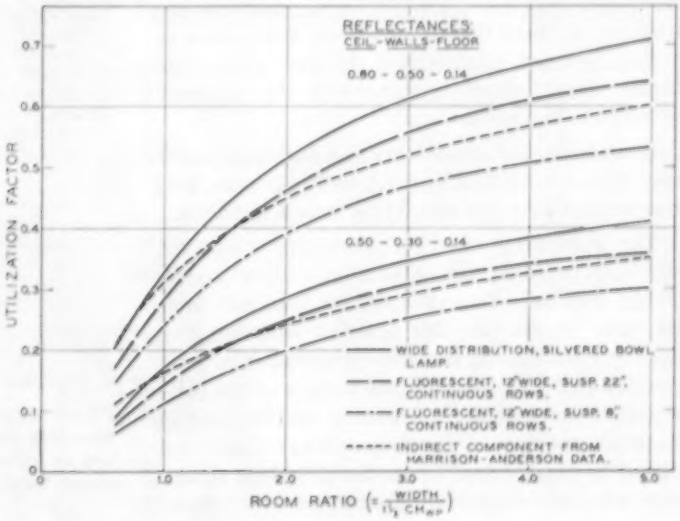


Figure 9. Utilization factors for indirect components. Data for wide distribution silvered bowl and continuous row fluorescent units at two suspensions taken from Table VI. Values have been interpolated for 14 per cent floor reflectance to facilitate comparison with Harrison-Anderson data.

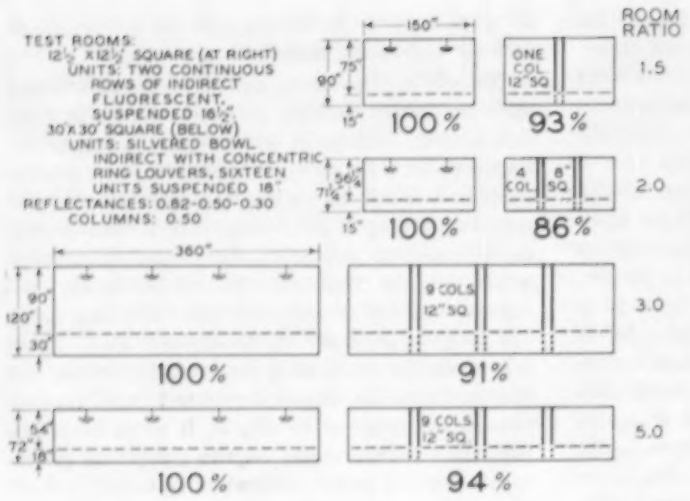


Figure 10. Examples of the effect of columns on average illumination on work-plane. Cross-sections of test rooms show the position of columns with respect to walls — columns spaced to divide room into equal sections. Simulated columns extended from ceiling to work-plane only. This allowed the lightcell to move freely. For simplification, the lighting units are left out of the cross-sections showing the columns.

sideration. Unfortunately, their large variety in size, number and reflectance presents many practical problems.

Measurements with a few types of obstruction in laboratory test rooms with reflectances of 0.82 - 0.50 - 0.30 were made to explore the effects for which corrections of utilization data may be necessary. For example, several sizes and patterns of square columns were used with indirect lighting in large and small size rooms. The observed utilization values, as shown in Fig. 10, ranged from 86 to 94 per cent of the corresponding values for an empty room.

Partial partitions also constitute obstructions with respect to a lighting system designed for the whole room. Such partitions, of the same reflectance (0.50) as the walls, were used in an indirectly lighted room of ratio 1.5 (F). They divided the room into four equal parts. Those partitions extending one-third the distance from work-plane to ceiling reduced illumination 17 per cent. The higher ones, extending two-thirds the distance, reduced it 34 per cent.

In an industrial space large and high equipment may reduce utilization as much as 50 per cent. This was verified in a test simulating such a condition.

The shadowing effect of a person, while not affecting average horizontal illumination appreciably, does have some effect on the illumination at his task. To evaluate this practical situation, two life-size simulated figures were constructed of composition board to represent the portion of the body above the work-plane in a writing position and in an erect position as for typewriting. Each was placed in three locations in the 12½-foot square test room and at several orientations with respect to the lightcell and lighting system. Results were weighted and averaged. The simulated figure for a writing position, shown in Fig. 11, reduced illumination at the task, 14 inches away, by 8 to 10 per cent. For the typing position, illumination 18 inches away was reduced only 3 to 5 per cent. Darley and Gaetjens,[15] working with direct continuous row units and a figure bent further over the site of the task, found reductions from 9 to 17 per cent. Obviously the shadowing effect of a figure will vary considerably with differences in placement of the figure, distance to task, and orientation with respect to the lighting units.

Figure 11. Showing one of the test set-ups used for determining the shadowing effect of a person on illumination at his task. Simulated figure represents an average person leaning forward in writing position with task 14 inches away.

Illumination on Vertical Surfaces

Illumination for vertical surfaces and seeing tasks is an important consideration in many lighting applications. However, relatively few studies in this field have been made.[15] In addition to the usual variables affecting illumination, the problems of location and orientation of the vertical planes of measurement must be considered. The authors have conducted some exploratory tests with both indirect and direct lighting systems.

These measurements of vertical illumination were of two types. For the first, the average vertical illumination over the whole space at work-plane level was investigated. In some tests this was determined by eight complete searches with the cell oriented in as many vertical planes at 45-degree intervals. In others it was found that the average of the eight could be represented by the average illumination at a selected single orientation. In either case, the illumination for all the planes could be expressed conveniently as a fraction of average horizontal illumination for the same conditions. For indirectly-lighted rooms with reflectances 0.80 - 0.50 - 0.30, this fraction ranges from 0.42 in a small room to 0.53 in a large room. In the larger rooms, of course, a greater portion of light to the work-plane is incident at wide angles. For direct lighting installations, one finds lower ratios of vertical to horizontal illumination depending on the flux distribution. For example, Fig. 12 shows ratios from 0.22 to 0.34 for reflector flood lamps with various shielding angles.

For the second type, measurements of illumination on the wall surface were made at different heights. Two indirectly-lighted rooms, ratios 3.0 (C) and 5.0 (A), with reflectances 0.80 - 0.50 - 0.30 were used. The surface of one wall was divided into four horizontal bands of equal width. The light-cell was mounted to read illumination on the wall along the center of each band. The two centrally-located bands, just above the work-plane, are usually of the greatest interest. They may constitute a background for a seeing task or they may represent the surface of shelves or displays. The average vertical illumination in these bands was $\frac{2}{3}$ of the average horizontal work-plane illumination over the whole space with this lighting system.

Summary

Utilization factors for downward components of luminaire output, as calculated by zonal multipliers and interflectance data, are in general close to the measured factors. This is the case in high-ratio as well as low-ratio rooms, and with systems of units either ceiling-mounted or suspended within the usual range of distances from the ceiling. Some cases, particularly at long suspensions, show differences in which the distribution of flux on the walls may be a factor. While utilization tables and charts may be constructed for each suspension condition of interest, the amount of change indicated suggests a nominal short suspension distance as a possible compromise leading to a reduction in the number of necessary charts and tables.

Tests and calculations indicate also that zonal multipliers may be developed for the direct component from fluorescent luminaires; in fact, they indicate that multipliers designed for individual small luminaires used in numbers (e.g., S/MH_{wp} of 0.4) can be employed for continuous row luminaires with little error, using conventional photometric data on such extended luminaires.

The authors have examined several types of flux ratio as indices to flux distribution and utilization factor, for a suitable flux ratio can conserve calcu-

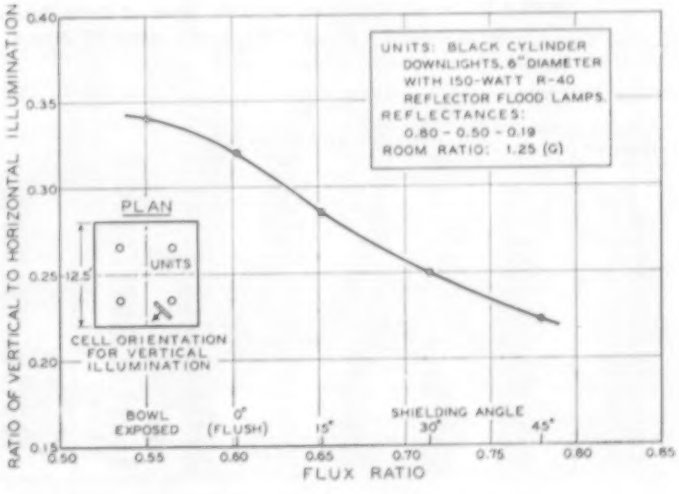


Figure 12. Ratio of vertical to horizontal illumination for downlights with R-40 flood lamps at various shielding angles. Lightcell, in vertical position, was oriented in direction shown in inset. This orientation was established by preliminary tests to be representative of the average of eight orientations 45 degrees apart.

lation time. A new type is presented, which, like that suggested by Meaker a year ago, eliminates subtractions of horizontal or other components. Charts illustrate its use for ready construction of utilization tables.

For upward components of output, new measurements have been made to extend the tables of utilization factors presented a year ago. Values in larger rooms are still higher than calculation indicates, but, as expected, the difference decreases. The effect of a change of flux distribution of a small source has been explored in large rooms. The results of extensive tests on the performance of the upward component of extended fluorescent units are presented in tables; they indicate that obstruction of the ceiling surface and the trapping of ceiling-reflected light are factors operating to reduce utilization substantially as compared with individual small luminaires. Obviously situations significantly different in this respect call for their own tables, or for the development of a suggested photometric procedure for evaluating the effect of this variable. Otherwise the above utilization factor tables based on typical arrangements of units may be used readily to obtain the upward coefficient of utilization.

Exploratory tests indicate that the effect of typical room obstructions should be evaluated and taken into account as utilization data become more accurate for empty rooms.

* * *

The authors acknowledge gratefully the counsel and assistance of their colleagues, Messrs. C. M. Cutler, Phelps Meaker, and R. M. Small.

Appendix

The principal Room Ratio values used in this paper are based upon the Harrison-Anderson equations. They are, for square rooms:

$$\text{Room Ratio (Direct)} = \frac{\text{Width}}{2\,MH_{wp}}$$

$$\text{Room Ratio (Indirect)} = \frac{\text{Width}}{1\tfrac{1}{2}\,CH_{wp}}$$

MH_{wp} = Distance from luminaire to work-plane.
CH_{wp} = Distance from ceiling to work-plane.

As this is written, these are the accepted equations. However, they give equal values of room ratio only when units are considered suspended a distance equal to ⅓ of CH_{wp}. The authors have pointed out[2] that a revision of the Room Ratio system is desirable to cope properly with all suspension conditions (including zero or flush-ceiling-mounted conditions) and the cases in which the usual division of lighting systems into "direct" and "indirect" causes confusion. For example, consider two rooms of the same dimensions. One has a transilluminated diffusing panel ceiling and is a "direct" unit. But an indirectly lighted ceiling which might have the same flux and brightness distribution and produce the same illumination would carry a different Room Ratio designation.

Potter has proposed[16, 17] that a simpler measure of pro-

TABLE IX.—Approximate Values of Floor Ratio for Values of Direct Ratio.

Direct Ratio	Floor Ratio
0.1	0.06
0.2	0.13
0.3	0.21
0.4	0.30
0.5	0.40
0.6	0.51
0.7	0.62
0.8	0.75
0.9	0.87

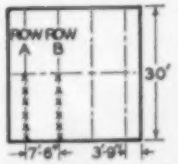


TABLE X.—Zonal Multipliers for Four Rows of Units Spaced 7'6", Room Ratio 2.0 (B), S/MH_{wp} = 1.0, Room 30' Square.

Zone (Degrees)	Row A						Row B					
	Inches, Distance From End Wall						Inches, Distance From End Wall					
	6"	38"	72"	106"	140"	174"	6"	38"	72"	106"	140"	174"
0-5	.930	1.000	1.000	1.000	1.000	1.000	.945	1.000	1.000	1.000	1.000	1.000
5-10	.678	1.000	1.000	1.000	1.000	1.000	.667	1.000	1.000	1.000	1.000	1.000
10-15	.600	1.000	1.000	1.000	1.000	1.000	.595	1.000	1.000	1.000	1.000	1.000
15-20	.566	1.000	1.000	1.000	1.000	1.000	.567	1.000	1.000	1.000	1.000	1.000
20-25	.550	.960	1.000	1.000	1.000	1.000	.553	.983	1.000	1.000	1.000	1.000
25-30	.483	.724	.919	.919	.919	.919	.541	.800	1.000	1.000	1.000	1.000
30-35	.411	.495	.788	.788	.788	.788	.533	.732	1.000	1.000	1.000	1.000
35-40	.376	.459	.705	.726	.726	.726	.528	.687	.982	1.000	1.000	1.000
40-45	.355	.419	.525	.682	.682	.682	.524	.653	.834	1.000	1.000	1.000
45-50	.336	.388	.455	.650	.650	.650	.520	.628	.761	.999	1.000	1.000
50-55	.320	.364	.417	.495	.626	.626	.516	.607	.709	.860	1.000	1.000
55-60	.309	.344	.385	.436	.542	.602	.472	.569	.588	.688	.863	.917
60-65	.296	.326	.359	.396	.444	.516	.398	.426	.461	.502	.584	.728
65-70	.287	.311	.351	.363	.337	.309	.342	.356	.384	.411	.396	.314
70-75	.277	.273	.250	.219	.191	.184	.223	.215	.167	.075	.028	.023
75-80	.074	.028	.042	.026	.015	.014	.026	.011	.003	.000	.000	.000
80-90	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

portions, adapted to present practice, be adopted. A single equation would be used, which, in effect, would make every system a "direct" lighting system. Its form for square rooms would be:

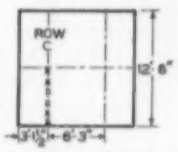
$$\text{Room Ratio} = \frac{\text{Width of room}}{\text{Distance from light source to work-plane*}} = \frac{W}{H_{wp}}$$

If this equation were used in this paper, all of the present Direct Room Ratios would be doubled. The present Indirect Room Ratios would be increased by 33 per cent; example values are shown in Table VI A, B and C along with present values and the letter index representing those values.

Used alone, the two present equations can serve equally well, but they are tied together by the assumed suspension condition. Consequently they are unsatisfactory for any other. The proposed ratio eliminates this difficulty. Where suspended "direct-indirect" units are dealt with, the two room ratio values (for MH_{wp} and CH_{wp}) applicable to this situation can be simply related for convenience at any specified suspension-to-CH_{wp} ratio chosen. When the ceiling is the designated light-source, this Room Ratio is the reciprocal of $k_r\, h'/h$ as used in interflection equations.

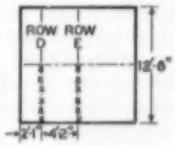
*The light source may be either primary (such as luminaire or exposed lamp), or secondary (such as the reflecting ceiling of an "indirect" system).

TABLE XI.—Zonal Multipliers for Two Rows of Units Spaced 6′ 3″, Room Ratio 0.6 (J), $S/MH_{wp} = 0.6$, Room 12½′ Square.



Zone (Degrees)	Row C					
	Inches, Distance From End Wall					
	6″	19″	31″	44″	56″	69″
0-5	.825	1.000	1.000	1.000	1.000	1.000
5-10	.613	.950	1.000	1.000	1.000	1.000
10-15	.569	.752	.960	1.000	1.000	1.000
15-20	.489	.574	.717	.908	.908	.908
20-25	.397	.439	.482	.545	.752	.753
25-30	.363	.394	.426	.465	.529	.684
30-35	.340	.365	.393	.422	.450	.476
35-40	.324	.346	.366	.398	.356	.289
40-45	.280	.281	.260	.208	.180	.175
45-50	.193	.138	.078	.046	.025	.012
50-55	.048	.022	.007	.000	.000	.000
55-90	.000	.000	.000	.000	.000	.000

TABLE XII.—Zonal Multipliers for Three Rows of Units Spaced 4′2″, Room Ratio 0.6 (J), $S/MH_{wp} = 0.4$, Room 12½′ Square.



Zone (Degrees)	Row D*						Row E					
	Inches, Distance From End Wall						Inches, Distance From End Wall					
	6″	19″	31″	44″	56″	69″	6″	19″	31″	44″	56″	69″
0-5	.850	1.000	1.000	1.000	1.000	1.000	.850	1.000	1.000	1.000	1.000	1.000
5-10	.626	.995	1.000	1.000	1.000	1.000	.618	.954	1.000	1.000	1.000	1.000
10-15	.500	.605	.860	.860	.860	.860	.571	.736	.984	1.000	1.000	1.000
15-20	.387	.438	.509	.688	.718	.719	.549	.656	.795	.988	1.000	1.000
20-25	.350	.389	.435	.494	.656	.660	.537	.616	.709	.815	.990	1.000
25-30	.329	.359	.393	.429	.487	.610	.529	.592	.661	.731	.833	.986
30-35	.314	.338	.365	.393	.427	.438	.421	.465	.493	.538	.665	.741
35-40	.302	.324	.346	.368	.342	.288	.286	.285	.286	.287	.254	.140
40-45	.294	.311	.317	.275	.235	.228	.227	.228	.194	.138	.036	.006
45-50	.208	.161	.099	.083	.015	.004	.170	.071	.029	.002	.000	.000
50-55	.059	.040	.021	.008	.002	.000	.017	.000	.000	.000	.000	.000
55-60	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
60-90	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

*Give double weight to Row D.

References and Footnotes

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8. *Footnote:* Utilization factor and room ratio values of the Harrison-Anderson system of data were based upon suspensions equal to ⅛ CH_{wp}.
9. Harrison, Ward, and Anderson, Earl A.: "Coefficients of Utilization," *Transactions of the Illuminating Engineering Society*, Vol. XV, p. 97 (1920).
10. *Footnote:* All charts in this paper containing flux ratio abscissae are based on these flux ratio weighting factors.
11. *Footnote:* The proper room ratio values for upward and downward components of output, based on the Harrison-Anderson equations, would be equal only when suspension distance equals ⅛ CH_{wp}. See discussion on room ratio in Appendix.
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17. Rebuttal and footnote 19 of Reference 2.

DISCUSSION

JOHN J. NEIDHART:* In 1951 when Messrs. Potter and Russell first described their new Laboratory for Lighting Design Data I noted the tremendous potentialities of this laboratory for obtaining a wealth of much-needed information. I now wish to congratulate the authors for their skillful use of these facilities in obtaining so much of this valuable data in a relatively short time. They are also to be commended for their clear and concise presentation of this mass of data.

It is particularly gratifying to see the theory of the direct component of the Zonal Method proved so conclusively under carefully controlled conditions. The excellent agreement shown by Table III proves that our calculations indicating the validity of the Zonal Method for extended as well as concentrated sources were correct and should forever quell the claims of others to the contrary.

Three years ago I expressed a dislike for the Flux Ratio concept of classifying direct distributions, because the flux ratio failed to recognize the significant effect of zonal flux variations on work plane utilization. The flux ratio proposed by the authors now recognizes these effects by dealing with 10° zones just as we did in the zonal method. The agreement between direct ratios obtained by the zonal method and those obtained through the use of the proposed flux ratio is remarkable. Time did not permit me to make extensive comparisons, but I did use the flux ratio to obtain direct ratios for several widely different distributions for which we had calculated direct ratios by the zonal method. These distributions included medium and wide spread batwing distributions as well as distributions more nearly representing cosine powers. The maximum difference in direct ratios that I found with these few examples was about 4 per cent.

As the authors show in Fig. 4, it is, of course, possible to eliminate the determination of direct ratios and obtain the downward utilization factors directly. Roy Jones and I had recently decided that accuracy would not be unduly sacrificed if we simplified the zonal method by plotting downward utilization factor against direct ratio. What the authors of this paper have done amounts to the same thing except that they have substituted their new flux ratio for the direct ratio, thus effecting even further simplification.

The fact that the zonal method yielded somewhat conservative coefficients for indirect luminaires in relatively small rooms was disclosed last year both by Potter and Russell and by Jones and me. I was glad to see the Potter-Russell data extended this year to show the greater accuracy of the zonal method in larger rooms. It was even more gratifying, however, to see a logical explanation this year for the divergence between theory and practice. Table VII indicates that the difference between the theortical *uniform* ceiling and wall brightnesses and the actual *non*-uniformity of these surface brightnesses results in a small net of conservativeness in the theoretical coefficients even though the non-uniform wall brightness partially compensates for the non-uniform ceiling brightness.

The upward utilization factors presented in Table VI *may* be the beginning of an accurate method of handling upward light. The many variables involved make the problem very complex, but I hope that the final solution will be something more mathematically straightforward than such a series of tables which may be improperly selected, interpreted, or interpolated so that the lighting designer would find it difficult or impossible to determine whether or not a given set of published utilization coefficients is applicable to his problem. Modification of the zonal method offers another avenue of approach which should not be disregarded. Recognition of the effect of non-uniform ceiling and wall brightness and the use of a more realistic suspension length should overcome the divergence which now runs as high as 16 per cent in small rooms. Perhaps a curve similar to Fig. 7 could be provided for each luminaire having a significant upward component, thus permitting a correction of the coefficients published in a single table to recognize suspension lengths other than the most common suspension length for which the table would be directly applicable.

Correction for the obstructing effect of the luminaires is a function of the number of luminaires employed and hence is dependent upon the illumination level. It seems more logical, therefore, for the lighting designer to make this correction rather than have it arbitrarily made by the manufacturer or laboratory calculating the coefficients. Appropriate correction factors should be published along with similar correction factors for columns, machinery, occupants, etc. When such correction factors become available and in common use we will have truly made a great step in the improvement of our engineering stature.

There is one desirable feature of the empty room calculations that we now make in that they have a common basis of calculation that leaves no room for the insertion of unjustified assumptions and fudge factors. Perhaps in the future we will find it expedient to show the calculated empty, unobstructed room illumination level as a basis for comparison as well as the calculated level that allows for obstruction and occupancy.

Although I heartily concur with Potter's objections to the present room ratio formula particularly from the standpoint of assumed suspension length, I do not believe that the suggestion he has submitted to the Lighting Design Practice Committee (and which is described briefly in the Appendix of this paper) is the solution for which we are looking. If his proposal were adopted, the lighting designer would have to work with two room ratios and two coefficients every time he employed a luminaire that had both upward and downward components. Such a system is cumbersome from both the design standpoint and the publication standpoint, and I hope that a more practical system can be developed. There is at least one other promising possibility which is already being studied by the Lighting Design Practice Committee, and I am sure that the Committee will give all proposals very careful consideration before adopting any new system.

KURT FRANCK:* In this paper the authors have extended their work of a few years ago and again, as before, their report is welcome indeed. The authors are continuing to succeed well in this important task of coordinating theory and practical measurements of utilization factors.

The idea of breaking down linearly extended luminaires into sufficiently small elements, for which the Inverse Square Law is valid, has been suggested before and can often be used to good advantage. However, a word of caution on the application of this method might be in order: It must be borne in mind that this breakdown into small elements cannot be limited to the evaluation of test results for practical illumination calculations, but must also be applied in the first place to the photometric test of the luminaire under

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*The Holophane Company, Inc., Newark, Ohio.

consideration. For that reason we believe that the authors are advising a somewhat doubtful method when in the paragraph directly preceding the section on "Obstructions—Other than Luminaires," they recommend the possibility of testing each unit and an associated section of reflecting ceiling which might be regarded as a direct lighting unit. While such a large "synthetic" luminaire might be tested accurately enough at large test distances of, say, 25 feet, it must not be overlooked that in actual application, where ceiling heights in the neighborhood of 10 and 12 feet prevail, a numeric evaluation of the photometric test values could lead to quite erroneous results; here the method of breaking the luminaire down into small sections may not work out because the "synthetic" luminaire, consisting of lighting unit plus associated ceiling section, has not only great length but also great width. It cannot be assumed that the small sections into which such a luminaire might be considered broken down would produce identical photometric distributions.

In Table IV we would be interested in the direct ratio values for a complete ceiling for the cosine cube distribution of narrow character. From the figures given for various row arrangements it can be estimated that the figures for the complete ceiling would be quite high, and we wonder whether the authors have actual test results or, if not, contemplate testing such an arrangement in their future work.

WARD HARRISON:* This paper supplies us with a great quantity of valuable new data which I imagine that we won't fully appreciate until we give it a great deal of study. I suspect also that the majority of us will not give it that necessary study; most practicing engineers are interested only in the final result, namely, a set of utilization tables which they know they can depend upon. Now a great mass of data alone is of little immediate use; in fact, it may just add to confusion. Fortunately, in this case the authors have analyzed and marshalled their data in such an orderly fashion that they are applicable at once.

Another group interested in utilization data are the fixture manufacturers who are called upon to publish tables for their equipment. A manufacturer wants not only accurate information but he wants it obtainable at a moderate expenditure. In other words, coefficient tables must not require an unreasonable amount of time in computation. This paper appears to combine the good features of all the new methods which have come to the attention of the Society in recent years and yet I believe that the labor of computing tables of coefficients should not be materially greater than for the old lumen method.

It might be appropriate to mention here what the inaccuracies of the older method were. One of them stems back to the fact that the experimental room measurements by Mr. Anderson and myself were made in 1915-1916. For nearly forty years after that no one in the industry saw fit to do any further comprehensive testing along these lines. Meanwhile, a host of new luminaires and some new light sources were developed with distributions very different from the older ones; notably very concentrating distributions.

In the absence of data, the old curves were extrapolated, which is always a hazardous venture. In some cases, those who made the calculations erred seriously, but it is fortunate that they always erred on the conservative side.

So much for discrepancy number one. As for number two, I still have a mental reservation. Our old tests were made using an uncorrected test plate and deliberately no attempt was made to correct our results although we knew that we were getting more light than we recorded. The errors ranged from about 4 per cent in small rooms with dark walls to about 12 per cent in large rooms. We knew that after a lighting design was made in accordance with the tables it would, if checked at all, be checked with meters reading at least as much too low as ours did. This would certainly have led to dissatisfaction and I would point out that nearly all meters in the field even today are of a type which read low. Luckily, fluorescent lamps, which are now the center of interest, give substantially more than their rated lumens for the first few days after they are installed and this fact may save you practicing engineers much embarrassment. If you get there quick enough, when measuring with a common uncorrected meter, you will still show as much light as you promised the client.

*Consulting Engineer, Cleveland, Ohio.

ANSON H. RUSSELL:* The authors wish to thank the several discussors of this paper for their kind and constructive comments. We are especially pleased to hear that the volume of data obtained from the laboratory was presented clearly.

We share Mr. Neidhart's pleasure that the measured data for *direct components* presented in our papers lends itself to easy correlation with mathematical treatments. However, we want to point out that the many variables involved in the handling of *indirect components* make a similar correlation very complex.

A thorough mathematical treatment of indirect components should take into account the following points:

(1) *Limitations of photometric data:* We are on uncertain ground in calculating zonal lumens from photometric candlepower data on luminaires of substantial size with respect to light incident on nearby ceiling surfaces.

(2) *Non-uniform brightnesses of room surfaces:* It has been shown in Table VII that there is a substantial difference between interflectance factors for theoretical uniform ceiling or wall brightness and the typically non uniform brightness pattern resulting from usual luminaires. Unlike direct lighting, computed utilization factors for indirect rely entirely on interreflections which are evaluated on the assumptions of uniformity and complete diffusion.

(3) *Spacing (number of units) and suspension of luminaires:* A previous discussion[1] of Messrs. Jones and Neidhart's paper has pointed out the unrealistic nature of the number of luminaires and suspension distance assumed in their mathematical treatment. For example, analysis shows that in an 0.6 (J) room, their zonal multipliers for the ceiling are based on 36 luminaires suspended at $^1/_5$ the ceiling-height-to-work-plane *(CH_{wp})* distance. Our data assume a more realistic arrangement of 4 units at about $^1/_5$ CH_{wp} suspension in a slightly larger room, room ratio 0.75. Table VIII points out the difference between ceiling ratios as calculated using the Jones-Neidhart concept of spacing and suspension, and the luminaire arrangement adopted for our tests.

(4) *Trapping of light by the luminaire:* Present mathematical methods take no account of light trapped by the luminaire. They give *higher* utilization for more concentrated upward flux distributions because of higher ceiling ratios. The great importance of light trapping as against flux distribution is well emphasized in our Fig. 7. Our tests show that as the upward flux distribution becomes more concentrated, a greater amount of light is trapped between

*Co-author.

the luminaire and the ceiling; this results in *lower* utilization, in spite of higher ceiling ratios. And in the case of rows of fluorescent luminaires the utilization drops even further (Fig. 7, Curve C).

Fortunately some of the errors in present calculation systems partially compensate each other so that final utilization factors are usually within 16 per cent of their measured values. However, these differences are difficult to predict since their occurrence depends on the multitude of variables present in any lighting system.

We believe that the reasonable approach to the problem of upward components is to utilize test data incorporating the many variables in several typical combinations and to classify installations according to the set of conditions which most nearly fits each. We feel that one table, Table VI-A, would be sufficient for most filament type luminaires at normal suspension distances, and that the fluorescent type luminaires could be bracketed by a few tables covering the range of suspension distances, opacity, and size of luminaires. With proper description of the conditions to which each table applies, most lighting designers would have little trouble in selecting the table most suitable. The advantage of simplicity is quite apparent; the tables give the utilization factor directly. Accuracy would be far more reliable than present systems which do not take into account light trapping by the luminaires.

Mr. Neidhart's suggestion of providing one table of utilization factors with an appropriate correction curve for suspension distance similar to Fig. 7 might be desirable. The choice between this form and several tables for different suspensions such as Tables VI B and C is largely a matter of preference. Our data could be expressed equally well in either manner.

Mr. Neidhart also suggests that the correction for the obstructing effects of the luminaires should be left with the lighting designer. We believe that this correction can and should be made on the basis of a typical spacing and incorporated in the utilization factor. Most of the light obstructed by luminaires is trapped by the particular luminaire (or row of units) which emitted that light, and therefore trapping is more a function of opacity and size of the source than the number of luminaires (or rows of units) used in an installation. To require the lighting designer to take this item into account would be to place upon him an additional burden which should be and is eliminated in using our suggested tables. We agree, however, that corrections for unpredictable obstructions should be left to the lighting designer after giving him a method of handling such obstructions.

While the room ratio which Mr. Potter has suggested in the Appendix to this paper requires the use of two room classifications in the *construction* of tables for a luminaire with both upward and downward components, it allows fixture suspension to be accurately dealt with separately. No arbitrary suspension need be assumed for all luminaires. However, in the tabulation of data *for use by the lighting designer*, room ratio for composite luminaires would be based on either fixture height or ceiling height, depending on the dominating component of luminaire output, just as they are today. The column heading would specify which dimension is to be used for the particular luminaire, and the tabulated coefficients would incorporate the total effect of both components. Coefficients for any desired number of suspension conditions could be separately tabulated.

As indicated in the Appendix, the range of numerical values from the proposed room ratio formula will be different from and will overlap the present range (0.6 to 5.0). However, this new concept of Room Ratio is not restricted to any particular set of numerical values. The present values of room ratio can be retained simply by dividing the proposed room ratio equation by a constant.

Mr. Franck's comments concerning photometry with a combination luminaire and ceiling section are in the main valid. However, he apparently assumes that photometric data for the "synthetic luminaire" would be applied to a ceiling area of the size photometered. The authors did not go into detail as to the application of this method. However, this objection is easily avoided by assuming that the synthetic luminaire is equal as to size, shape and position of the actual luminaire. This hypothetical luminaire then lends itself to breakdown into increments as Mr. Franck has agreed.

The ideal procedure involving many tests with simulated ceiling sections and variable suspension was not mentioned with the thought that it be recommended for commercial testing.

In Table IV the direct ratio values for a complete ceiling of cosine distribution were computed from Ziro Yamauti's exact equation.[2] To our knowledge, there is no similar equation for the cosine cubed distribution. An approximate solution may be obtained from Moon and Spencer's work[3] which is based on an infinitely long room. The values for a complete ceiling from this source for J and E rooms are:

	Constant cp.	Cosine	Cosine Cubed
0.6 (J)	.181	.275	.396
2.0 (E)	.448	.619	.757

We have not planned to test a complete ceiling of the cosine cubed distribution in our laboratory. Coefficient data on acrylic and vinyl plastic luminous ceilings are in preparation, however, and should be available in the near future.

Messrs. Harrison and Anderson's work on utilization has certainly stood up over the years, and is an important milestone in the development of illuminating engineering. As Mr. Harrison indicates, the data must be expanded and adjusted to meet present needs. The development of new light sources with concentrated downward distributions and large area fluorescent luminaires with upward components point up this need.

With the rapid advancement of lighting design techniques, more accurately cosine-corrected lightmeters are imperative. The lighting industry has developed highly improved cosine correction methods for lightmeters even in the "pocket lightmeter" size. These are beginning to replace the uncorrected type in the field.

References

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2. Yamauti, Ziro: "The Amount of Flux Incident to Rectangular Floor through Rectangular Windows," *Researches of the Electrotechnical Laboratory*, Tokyo, No. 250 (1929).

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INSTALLATION AT LAS VIRGENES UNION SCHOOL, CALABASAS, CALIFORNIA.

Lighting a Classroom

LIGHTING OBJECTIVE: To illuminate a classroom by coordinating the electric lighting with daylighting.

GENERAL INFORMATION: Surface characteristics of this 30- by 30½-foot school classroom are as follows:

walls	light green	60% RF
floor	tan	30% RF
desk tops	natural tan	35% RF
ceiling		
acoustic tile	pink beige	55% RF
cavity above plastic	white	80% RF
chalkboard	green	40% RF
tackboard	tan	40% RF

The finished ceiling slopes from 10 feet high down to 8 feet high (see Fig. 2).

INSTALLATION: Nine 96-inch T-12 standard cool white slimline lamps are mounted 4 feet on centers in three continuous rows of three lamps each, from 10 inches to 3 feet 4½ inches above an Acusti-luminus ceiling installed in the south-half of the classroom. Four pendent mounted concentric ring luminaires using 300-watt silver-bowl lamps are mounted 7½ feet by 15 feet in the north-half of the classroom. The slimline fixtures are manufactured by the Light Control Co. (catalog number LC-571-96); the Acusti-luminus ceiling is manufactured by Luminous Ceilings, Inc., and the incandescent luminaires are manufactured by the Smoot-Holman Co. (catalog number RK-500 S).

(over)

A.I.A. File No. 31 f

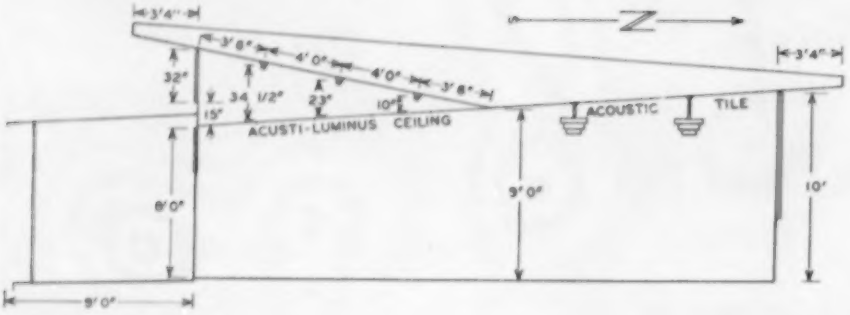
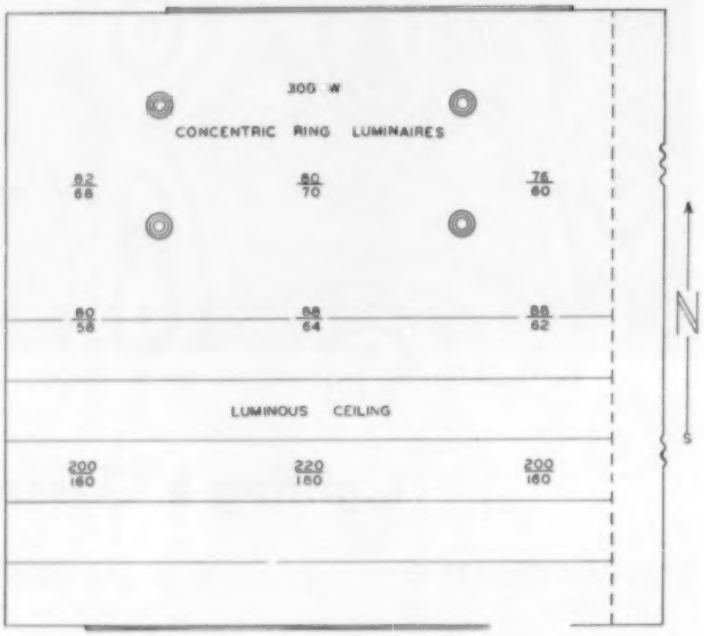


Figure 2 (above)

Figure 3 (right) Average footcandle values shown as follows:

$$\frac{\text{Average footcandles daylight plus electric light}}{\text{Average footcandles daylight}}$$



Brightnesses are indicated below

Ceiling:	
luminous ceiling	85 ft-L
acoustical tile ceiling above luminaire	160 ft-L
acoustical tile ceiling between luminaires	25 ft-L
Walls	
front	32 ft-L
side	24 ft-L
chalkboard	27 ft-L
tackboard	26 ft-L
floor	23 ft-L
desk tops	20 ft-L

Since this installation is designed to have the electric lighting supplement the daylighting, the average footcandles shown in Fig. 3 were taken at 2:00 p.m. on a bright sunshiny day. As shown in Fig. 2 the light from the Acusti-luminus ceiling is supplemented by daylight from windows above the ceiling.

Architect: Flewelling and Moody, Los Angeles, California.

Lighting data submitted by D. R. Shields, lighting consultant, Southern California Edison Co., Fullerton, California as an illustration of good lighting practice and to aid in the design of similar installations.

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Little League Baseball—Major League Lighting

YOU MAY be looking at the home run king of the 1970 World Series in the above picture. If so, he's about ten years old now, and already is playing ball under the lights, Major League style.

The field, an official Little League Ball Park in Huntingdon, Indiana, is 315 feet from home plate to right field foul line, with the stands located behind the plate. A professional level of night-ball illumination is furnished from a floodlighting layout using eight 55-foot poles. The four poles lighting the infield are placed: one on each side of home plate, 30 feet out from the base paths; one just beyond first base, 25 feet out from the foul line; and one just past third base, 25 feet out from the line. Each of these poles is equipped with ten 1500-watt floodlights in elliptical luminaires, six lights on a 10-foot crossarm, and four on an 8-foot crossarm.

Four similar poles but with single crossarms light the outfield. These use six floodlights each, 1500-watt, 115-volt clear lamps.

Layout and supervision of the installation was the work of Dayton T. Fortner, Public Service Company of Indiana in Kokomo.

Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of H. F. Davidson, has prepared these answers to questions concerning light sources. Readers are invited to submit similar questions of general interest to be considered for publication. Questions should be sent to the Committee in care of Society Headquarters.

Why does my installation of 96T12 lamps fail to light in high humidity weather after they have been in service for some time?

All instant start and rapid start lamps have a silicone coating on the glass to prevent formation of continuous moisture films in high humidity. If lamps are used in locations where a layer of dirt or other films have accumulated on top of the coating, the effect of the coating can be nullified and a moisture film on the dirt can cause unreliable starting. Under these circumstances, more frequent washing is recommended.

I want to use an electric welder on the same panel board as my fluorescent lighting. The welding apparatus will cause a voltage dip of ½ of one per cent, 60 times per minute. Will this result in perceptible flicker, and if so will it be severe enough to be objectionable?

From the limited published data on this subject it is expected that ½ of one per cent voltage dip each second would not be objectionable for a fluorescent lighting installation. This is based on two sets of data. From Reference (1) it is indicated that for a 15-watt fluorescent lamp subjected to 60 voltage dips per minute, the duration of the dip being one cycle and five cycles, the average borderline of perception for eight observers was a voltage dip of about 0.75 per cent. From Reference (2) using two 40-watt fluorescent lamps 4500 white on a lead-lag ballast, 60 voltage dips per minute, duration of dip ¼ second, the average border-line of perception for six observers was 1.6 per cent while the average borderline of objection was 2.4 per cent.

In both References (1) and (2) the observers were reading printed matter illuminated by the lamps under test, but the lamps were not in the observers' field of view.

It should be noted that ½ of one per cent voltage dip is about the least that could be expected from an electric welder. Voltage dips as high as 50 per cent for a cycle or so are possible and such dips could cause noticeable flicker. It is usual to calculate the voltage dip although it can be measured with instruments that have sufficiently high speed of response.

References

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2. Davidson, G. E.: "Flicker in Lighting Systems," *Ontario Hydro Research News*, Vol. 4, No. 4, p. 9 (October 1952).
3. Weise, W. R.: "Cyclic Flicker of Fluorescent Lamps," *Electrical World*, Vol. 124, p. 80 (October 27, 1945).
4. Eastman, A. A. and Campbell, J. H.: "Stroboscopic and Flicker Effects from Fluorescent Lamps," ILLUMINATING ENGINEERING, Vol. XLVII, No. 1, p. 27 (January 1952).

One of our customers has built a fixture using two 42T6 fluorescent lamps on a 48T12 ballast to obtain extra light output, at a sacrifice in lamp life. However, the lamps flicker. What is the cause of the flicker and how can it be corrected?

The 42T6 lamps will flicker when operated on a 48T12 series-sequence ballast. The 42T6 lamp has a higher starting and operating voltage than the 48T12 lamp. The higher voltage requirement of the 42T6 lamp and the inherent characteristics of the series-sequence circuit cause the flicker. Series-sequence ballasts should be used only with the lamps for which they are designed or recommended.

The flicker can be eliminated by using a 48T12 lead-lag ballast. It should be noted that the light output of the 42T6 lamps at the higher current is likely to be lower than expected unless low ambient temperatures are involved.

GENERAL GUIDE TO PHOTOMETRY — A report of the I.E.S. Committee on Testing Procedures for Illumination Characteristics. In this issue are Sections 6 and 7. Sections 1, 4 and 5 were published in the March issue of IE; and Sections 2 and 3, on Characteristics of the Eye and Nomenclature and Units, will be included in the reprints of the full report.

Section 6—General Guide to Photometry

Methods of Measurement

6.1—*General* — Measurements of luminous flux, luminous intensity, and illumination by visual photometry reduce in the final analysis to the comparison of the photometric brightness of a test surface with that of a comparison surface. It is advantageous and usually possible to arrange the conditions under which measurements are made so that the photometric brightness of the comparison surface need only be constant but need not be known.

6.1.1—*Measurements of Electrical Supply Values*— **(a)** The voltage supply and the electrical instruments used to measure the voltage, current, or wattage need particular attention in photometric work. Lamps must be operated under constant, reproducible, and specified conditions. An a-c voltage supply should be stabilized with a device which does not produce a distorted wave shape.

(b) The meters used will probably be of one of the six types discussed below. The allowable limits for meter losses are covered in detail in the *IES Guide for the Electrical Measurements of Fluorescent Lamps.*

Electrodynamic—The deflections of electrodynamic instruments depend upon rms values and they can be designed for accurate measurements over a moderate range in frequency. They are readily calibrated on direct current and maintain calibration well. Most electrodynamic instruments have fairly large potential and current circuit losses, but designs are available whose losses are within the allowable limit.

Electrostatic—In most designs, the deflections of electrostatic instruments depend upon rms values and they are accurate over a wide range in frequency. Their potential circuit losses are very low but because of their low deflection torque they require a fairly long time to reach a steady deflection and are subject to zero shift.

Iron-Vane—The deflections of iron-vane instruments depend upon rms values and they can be designed for use over a moderate range in frequency. As in electrodynamic types, a design whose potential or current circuit losses are within the allowable limits must be chosen.

Thermal—The deflections of thermal instruments depend upon rms values; they are accurate over a wide range in frequency, and their potential or current circuit losses are usually quite low. However, their calibration depends upon instrument temperature — the change being from 0.1 to 0.3 per cent per degree Centigrade. Therefore, it is very important that the instrument temperature be maintained uniform and constant (no sources of heat located near the instrument) and that the instrument be calibrated at the same temperature at which it is used.

Rectifier — The deflections of rectifier instruments depend upon average values and therefore they cannot be used to measure the rms value of a distorted wave.

Electronic — In most designs, the deflections of electronic instruments depend upon peak or average values and thus should not be used for rms measurements. An investigation of their accuracy for use in fluorescent lamp circuits should be made before using them.

6.1.2—*Visual Photometer* — **(a)** A complete visual photometer consists of one of the various photometer heads (see Section 5.1) which presents two surfaces to the eye for comparison, and some means for varying the photometric brightness of one or both surfaces in a known manner so that a photometric balance may be obtained. The illumination, and hence the photometric brightness, of the surface (or surfaces) is varied according to some known law, the most common methods of doing this being by: (1) varying the distance of one or both sources from the photometer screen, interposing a rotating sector disk or some absorbing medium between one of the sources and the surface it illuminates to extend the range; and (2) polarizing the light from the two surfaces in planes perpendicular to each other and using a rotatable Nicol prism to obtain a photometric balance. Combinations of these methods are also commonly used.

(b) When the distance is varied there are four methods of arranging the lamps, photometer head, and variable distance. These are shown in Fig. 11. In (1) if one source, L_1, is at the zero of photometer bench, while the other, L_2, is at a distance d from it, and the photometer head, H, is at a distance x when a balance is obtained, the ratio of the candlepowers is $(d-x)^2/x^2$. Because of the incon-

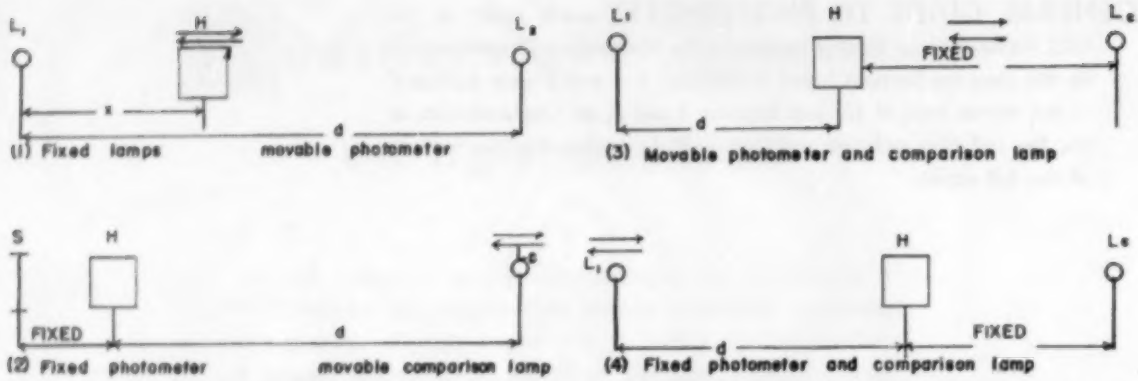

Figure 11. Four common methods of arrangement of apparatus on a horizontal bar photometer. The first method (top at left) is not often used because the ratio of candlepowers measured is not expressed by the simple relationship as in the other methods. The second method (below at left) is convenient when the test source is large, as, for example, the window of an integrating sphere. The last two methods (right) permit the use of a constant field brightness.

venience in computation, this method is not often used. In each of the other methods, it is obvious that when sources are placed in turn at various distances, d, from the head the ratio of their candlepowers is inverse to the ratio of the squares of their distances. There are substitution methods (L_1 being, for example, first a standard and then an unknown) and in addition to simplifying the calculations their use compensates for any inequalties in the optical paths of the light reaching the respective halves of the photometric field. Method (2) is used when one source is not easily moved, as, for example, when it is the window of an integrating sphere. Methods (3) and (4) permit the use of a constant photometric brightness of the comparison field.

6.2—*Measurement of Illumination* — **(a)** The illumination at any point upon a surface may be defined as the areal density of the flux incident upon that surface at that point. When using a visual photometer to measure illumination the test surface may be observed by either reflected or transmitted light and should be a diffusing, non-selective surface. Any departure from perfect diffusion will not result in errors if the angles of incidence and view are kept constant. Where either angle cannot be kept constant, plaster of Paris, compressed powdered magnesium oxide or carbonate, "smoked" magnesium oxide, depolished white enameled iron, depolished porcelain and depolished pot-opal glass may be employed as test surfaces and will depart but little from the properties of a perfect diffuser for angles of incidence and view in the same plane as and on the opposite side to the incident light not exceeding about 30 degrees. When the test surface is observed by transmitted light, depolished pot-opal glass is usually employed. The angle of view is generally fixed and is most often normal to the surface opposite that on which the light is incident. The criterion of performance for both the reflecting and transmitting test plate is that the photometric brightness in the fixed direction of view be independent of the direction of the incident flux (assuming this flux to be constant per unit area regardless of direction).

(b) The use of photoelectric or radiometric photometers to obtain *relative* values or the variations of illumination that take place at any particular point is accurate so long as the measurements are of light of identical spectral composition. Otherwise difficulties are introduced by the departure of the spectral response characteristics from those of the human eye as represented by the standard luminosity curve. Many of these photometers have surfaces which depart importantly from the properties of a perfect diffuser and should not be employed without correction when light incident at angles greater than about 40 degrees to the normal is important.

(c) Methods of correcting for the cosine error by means of special shapes[16] and compensated test plates have been developed. It is also possible to measure the illumination perpendicular to the direction of the incident light and calculate the illumination on a surface inclined to this direction. Angles must be measured carefully. See Section 4.2.

(d) The scale of any illumination meter must be calibrated and it is necessary to have a known value of illumination to check the device. The most accurate means of doing this is to mount a standardized lamp on a photometer bench and to place the receiver surface with the plane of its surface normal to the incident light and at known distances from the standard lamp. In addition to the above calibration the departure from the cosine law should be determined by orienting the receiver surface at various angles to the photometer-bench axis.

6.3—*Measurement of Luminous Intensity*—(a) Luminous intensity as an entity is not measured in practical photometry. A photometer is used to measure the illumination on a test surface at a measured distance (see Section 4.1 (b) and Fig. 5) from the source being measured. The usual practice is to use a substitution method; in this case the luminous intensity

is proportional to the illumination, and since a ratio is used, the actual illumination is not calculated. The angle of incidence on the test plate is kept constant (in fact, apparatus is usually arranged for normal incidence) and hence departures from perfect diffusion of the test plate have no significance.

(b) In photometric and radiometric photometry the illumination (assuming that correction to the standard luminosity curve has been made) on the receiver surface is measured and the luminous intensity is, again, calculated from the inverse-square law.

6.4—*Measurement of Luminous Flux*—(a) The luminous flux from a source is evaluated by using some form of integrator. When the total flux is to be determined, the most desirable form of integrator is a hollow sphere with a diffusely reflecting inner surface.[17] Any regular geometric shell may be used, but the sources being compared must be carefully positioned and have nearly identical flux distributions for valid comparison of their total flux when the integrator is other than spherical.

(b) Another method of obtaining the luminous flux from a source is by calculation from measurements of luminous intensity in a number of directions, measurements being made in a sufficient number of directions to obtain an accurate knowledge of the distribution of luminous intensity (see Section 6.6 (e)).

(c) In the case of the integrating sphere, the theory assumes that the inner surface is perfectly diffusing, that the reflection factor is constant over the whole surface, and that the sphere is perfectly empty, so that the reflected flux is entirely undisturbed by the presence of objects within the sphere. With these assumptions it follows that the illumination and hence the photometric brightness of any part of the sphere wall due to *reflected light* only is proportional to the total flux from the source, irrespective of its distribution. Obviously, the fact that a source of finite dimensions is placed in the sphere, the necessity of having an aperture or window in the sphere wall in order to measure the illumination due to *reflected* flux, the use of a shield or baffle to prevent *direct* light from the source being measured, and the presence of the necessary supports, socket, and wires all are departures from the basic assumptions of the theory. The various elements of uncertainty entering into the considerations of a sphere as an integrator make it undesirable to use a sphere for the absolute measurement of flux but do not detract from its use when a substitution method is employed.

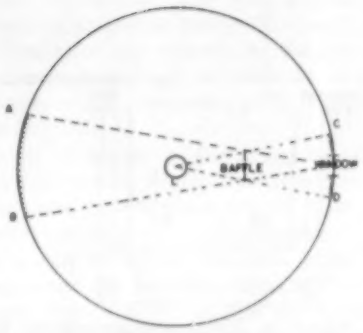

Figure 12. Effect of source and baffle within sphere. In theory the integrating sphere is empty and the source is a point. The use of a baffle to screen the window from direct light means that light from the indicated areas cannot reach the window by a single reflection. These "screened" areas should be kept as small as practical.

(d) The effect of the shield or baffle can be seen by reference to Fig. 12. The baffle prevents flux from the source from falling directly on the zone *CD* (including the sphere window) and results in the window not receiving flux from the zone *AB*. When the light source is at the center of the sphere, it can be shown[17] that the sum of the screened areas is a minimum if the baffle is at a distance from the center of from 0.3 to 0.4 times the radius of the sphere. The baffle and any other obstructions should be painted with the same paint as that used on the sphere wall and should be as small as possible consistent with adequate shielding.

Figure 13. Arrangement of sources and baffles for the simultaneous method. This method is used when the test source has a considerable superficial area. Since the test source is always present, the disturbance of the reflected flux distribution by this source is nearly the same for all measurements.

(e) The window must be mounted flush with the inner surface of the sphere wall. Depolished pot-opal glass is quite commonly used for this purpose. The criterion for judging the suitability of any material for use as the window of a sphere is that the photometric brightness in the direction of view (that is, the direction to the photometric device — usually fixed) is independent of the direction of the incident flux. The area of the sphere window should be small. In most spheres the photometric brightness of the external surface of the window is used as a measure of the illumination of the inner surface. There seems to be no particular reason why this method is more generally employed than the more direct one of measuring directly a properly shielded portion of the inner surface of the sphere wall with a photometer.

(f) The paint used on the inner surface of an integrating sphere (or enclosure) must be non-selective and diffusing. Several laboratories have developed satisfactory paints in the last few years.*

(g) There are two common methods of using an integrating sphere. The first is a true substitution method where the standard lamp (or lamps) and the test lamp are placed in turn in the sphere socket at the center of the sphere (as shown in Fig. 12). In the other method, known as the "simultaneous" method, both standard lamp and test lamp (or unit) are in the sphere throughout the measurements; this arrangement of lamps and screens is shown in Fig. 13. The first measurement is made with the standard lamp, L_s, alone lighted. The second measurement is made with the test lamp (or

*"Sphere paint" is available from Benjamin Moore and Company, 511 Canal Street, New York, New York and the General Electric Company, Nela Park, Cleveland, Ohio.

unit), L_t, alone lighted. When L_t is a luminaire or source, such as an arc lamp, where the luminaire or necessary auxiliary equipment has a considerable superficial area, the disturbance of the reflected flux distribution in the sphere by this apparatus is then nearly the same for both measurements. The extent of this disturbance may be further reduced by painting as much as possible of the external surface of the luminaire and auxiliary equipment with sphere paint or by covering it with a white matte material such as white blotting paper. Three baffles S_1, S_2 and S_3 are required; the first, S_1, is needed to prevent direct light from either source from reaching the other source and the other two, S_2 and S_3, are needed to shield the sphere window from direct light from L_s and L_t, respectively. The positions of L_s and L_t should be as nearly as possible symmetrical with respect to the sphere window, but they should not be too close together or the size of S_1 will be excessive. The sources, L_s and L_t, should not be close to the surface of the sphere. A compromise is to place each source about midway between the center of the sphere and surface. The areas of all the baffles are kept as small as possible while providing adequate shielding and they are, of course, painted with sphere paint.

(h) A variation of the simultaneous method is to take, first, a reading with the standard lamp lighted alone and with all baffles in place, then a reading with the standard lamp lighted and with the test lamp (or unit) mounted in the sphere, but not lighted, and finally, a reading with the test lamp alone lighted, the standard lamp being in the sphere but not lighted. The first and second readings give a measure of the absorption and disturbance of flux caused by the introduction of the test lamp or unit into the sphere. This factor is then used to correct the results obtained in the third reading.

6.5—*Measurement of Photometric Brightness*— (a) The definition of photometric brightness suggests that for a surface it is only necessary to determine the luminous intensity in a given direction and divide this by the projected area of the surface in that direction.[18] In practice, however, this direct method cannot usually be applied since the surface must be measured from a distance sufficiently great for the surface to be considered to be a point, so that the inverse-square law will be valid, and often the area cannot be determined with sufficient accuracy. If the surface is of sufficiently high photometric brightness the use of a diaphragm with an aperture of accurately known area placed close to the surface will permit the direct method to be used. An aperture in the form of a square of 1-inch side or a circle of $1\frac{1}{8}$ (1.1284)-inch diameter are convenient and the measured luminous intensity, expressed in candles, will give at once the photometric brightness in candles per square inch. For the inverse square law to be valid the distance from a one-inch square would need to be about 1 foot (error to be about one-half of one per cent).

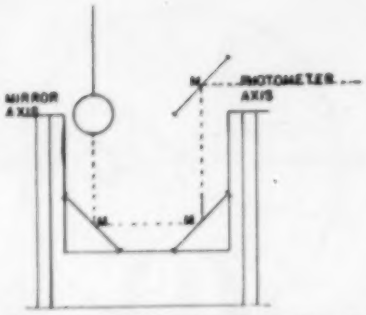

Figure 14. Distribution photometer. In measuring the distribution of light around a source some system of mirrors is employed. One such arrangement that may be used when the ceiling height is comparatively limited is illustrated.

To be sure that the eye of the observer is in the photopic range the illumination produced on the screen of a visual photometer should be at least 2 footcandles (allowing for about 50 per cent absorption in the photometer). Hence, the photometric brightness of the surface being measured would need to be around 2 or 3 candles per square inch for the direct visual method to be applicable.

(b) In other cases, a diffusing surface, for which the reflection factor for specific conditions of incidence, spectral energy distribution, and angle of view is known, is used either as a means of calibrating a photometer (with a given illumination provided) or for matching the photometric brightness of a comparison surface. The photometric brightness of the test surface is the product of the luminous reflectance (reflection factor) for the specific conditions (determined by careful laboratory measurements) and the illumination in footcandles. This product is in footlamberts, which, when divided by π is expressed in candles per square foot or, when divided by 144π is expressed in candles per square inch.

(c) In the above discussion it is assumed that the photometric brightness being measured is sufficiently great that the observer's eye is in the photopic state. This occurs when the value is above 1,000 microlamberts (1 millilambert or 0.929 footlamberts, which is produced by approximately 1 footcandle on a perfectly reflecting, perfectly diffusing surface). When the value is much below 1,000 microlamberts the special technique described in Section 6.8 should be used.

6.6—*Candlepower Distribution*— (a) In many applications the distribution of luminous intensity (candlepower) about a source is of more interest than a measurement of total flux. Furthermore, knowledge of the flux distribution in zones is of great value in predicting utilization of light. Two luminaires may have the same light output but widely different distributions of luminous intensity, one being suitable for totally indirect lighting with all the flux being directed upward while the other is suitable for direct lighting and has only downwardly directed flux. In another application, the fundamental standards of luminous flux, which are used to calibrate other lamps by use of an integrating sphere, must be evaluated by measuring the distributions of luminous intensity and calculating their total flux (see Section 6.6 (f)).

(b) The distribution around a source (lamp or luminaire) may be determined by positioning it on an axis of symmetry and determining the mean intensities* at various angles in planes passing through the axis about which the lamp is moved.[19] This could be done by moving the photometer on an arm pivoted on a horizontal axis passing through the light center of the lamp. Since most visual photometers are rather bulky and the observer must be at the photometer head, it is cus-

*The mean intensity may often be determined by rotating the source at about 50 rpm about its axis.

tomary to use a system of mirrors which bring the light to the photometer. One such system is shown in Fig. 14. When a photoelectric photometer is used, it is possible to mount the receiver on an arm that rotates about the horizontal axis through the light center of the lamp.

(c) Since the distance from the source to the receiver should be great enough for the inverse-square law to be valid (the distance can be shortened somewhat in cases where relative values only are desired), the arm would be excessively long when measuring such extended sources as some fluorescent tubes. To conserve space the National Bureau of Standards has constructed its large distribution photometer in the form of a ferris wheel as shown in Fig. 15. The light from the source centered in the wheel travels to mirror *M* (one spoke being omitted in the drawing to show the light path) and thence to a photoelectric cell, *P*. Baffle B_1 prevents light from being reflected by the mirror to the cell from the walls, while baffles B_2 and B_3 (with circular apertures) prevent light from directions other than the mirror from reaching the cell. This arrangement permits the use of a 25-foot photometric distance in a 20-foot space; a single-arm distribution photometer would require a 50-foot diameter for a complete arc around the source.

(d) Luminaires or large bulky sources which ought not to be rotated to obtain an average value must be measured in a number of vertical planes to insure that the average is sufficiently accurate for the intended purpose. For example, the minimum number for a luminaire using fluorescent lamps would be three, one in a plane parallel to the tubes, one in a plane perpendicular to the tubes and one intermediate plane at 45 degrees to the other two, all realized by orienting the luminaire.

(e) The zero of the scale of angles in the vertical plane is customarily taken at the bottom, directly beneath the source for general lighting luminaires. The angles in the vertical plane at which readings are taken will depend upon the nature of the distribution curve; if the flux is confined to a narrow zone or varies greatly with the direction of view, a number of measurements at closely spaced angles will be required. For most general lighting luminaires sudden changes in distribution are avoided by the designer and readings are taken at 10-degree steps, commencing with 5 degrees.

(f) To obtain the flux in any zone, or for the total flux, it is necessary to use zone factors which are the zonal areas on a unit (radius) sphere.[20] The zone factor is the difference in the cosines of the bounding angles of the zone multiplied by 2π. For the customary 10-degree zones used in measuring luminaires the factors are those given in Table V. If the lamp (or lamps in a multiple lamp unit) in the luminaire is operated at rated lumen output while the distribution curve is obtained, the computed total output from the luminaire divided by the rated output of the lamp is the efficiency of the luminaire.

(g) The Illuminating Engineering Society publishes recommended testing procedures[21] for various types of lighting devices, luminaires and fixtures and these procedures should be followed whenever possible. These procedures are reviewed and revised from time to time.

6.7—*Measurement of Beam Candlepower*—(a) In the case of beam projection apparatus, the candlepower in various parts of the beam is measured and the light output, expressed in lumens, is calculated from the distribution of beam candlepower. It is customary to determine the illumination at a known distance from the searchlight and calculate the luminous intensity of an hypothetical point source which at that distance would produce the same illumination. The term "apparent candlepower" is used for this value; the distance used in making the measurements should always be stated so that an estimate of the magnitude of the errors to which the measurements are liable may be made.

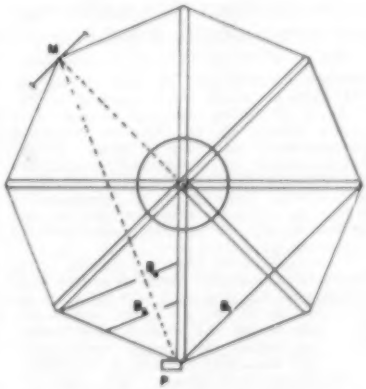

Figure 15. Large distribution photometer at the National Bureau of Standards. The light from the source centered at *L* travels to mirror *M* and thence to a photoelectric cell *P*. The arrangement permits the use of a 25-foot photometric distance in a 20-foot space; a single-arm distribution photometer would require a 50-foot diameter for a complete arc around the source.

TABLE V.—Zone Factors—10-Degree Zones.

Mid-Zone Angle	Zones	Zone Factor
5, 175	0-10; 170-180	.0954
15, 165	10-20; 160-170	.283
25, 155	20-30; 150-160	.463
35, 145	30-40; 140-150	.628
45, 135	40-50; 130-140	.774
55, 125	50-60; 120-130	.897
65, 115	60-70; 110-120	.993
75, 105	70-80; 100-110	1.058
85, 95	80-90; 90-100	1.091

(b) The "edge" of the beam is commonly taken at the line along which the apparent candlepower is equal to $^1/_{10}$ the average of the 10 maximum apparent candlepower readings taken in accordance with the *IES Guide for the Photometric Testing of Floodlights of 10 to 160 Degrees Total Beam Spread*.[23] The beamspread is taken at the angle subtended at the projector by a line running from one edge of the beam to the other.

(c) The photometric distance required[22] (the photometric range) often necessitates the use of an outdoor range. The transmittance of the atmosphere over the range must be compensated for. This may be done by use of a permanently mounted auxiliary searchlight for which the apparent candlepower can be determined on a short indoor range. The use of a photoelectric photometer and recorder with this searchlight is a great convenience if an extended series of measurements is to be made.

(d) When measurements are made outdoors in daytime extremely careful shielding of the photometer is required. A reading with the projector turned 180 degrees from the photometer or otherwise obscured should be made periodically to determine the contribution of the background around the projector. This "blank" or "no-light" reading is subtracted from all beam measurements. When tests are

made infrequently, it is preferable that they be made at night to avoid the need for considering the background contribution to the measurement.

(e) For small beam projectors having a fairly wide spread, such as those used for floodlighting and for automobile headlights, the test methods outlined in the recommended test procedure of the Illuminating Engineering Society and/or the Society of Automotive Engineers[28] should be followed.

(f) Beam projectors are customarily mounted on a goniometer and rotated about vertical and horizontal axes to obtain the candlepower distribution. In processing the results the projector is considered as fixed, and the angular deviations at which the measurements are taken are plotted. However, since actually the photometer is fixed and the projector is rotated, when the projector is turned "to the right upward" the direction of measurement with respect to the axis of the beam has a deviation "to the left downward."

(g) Since the candlepower in a beam may vary rapidly from point to point, the receiver should be some type of integrator which integrates the flux received over a definite fraction of a square degree. For small projectors and floodlights where a photometric distance of 100 feet may be used without introducing appreciable departures from the inverse-square law, an integrator accepting the flux in a square degree is recommended (20.94 × 20.94 inches at 100 feet).

(h) A sphere will also integrate the flux in a beam of light projected into it through an aperture. Its use in this manner requires extra care in placement of baffles and in being certain that the sphere wall is closely a perfect diffuser. Such measurements are usually made by measuring the brightness of the sphere window or sphere wall by one of the methods described in Sections 6.4e and 6.5.

(i) Two types of goniometer are in common use.* In the first the horizontal axis of rotation is a shaft contained in bearings in the fixed frame. The apparatus turns first around this fixed horizontal axis, and then also around an axis starting in the vertical position and following the rotation about the horizontal axis (Fig. 16). It is also possible, however, to have the vertical shaft in fixed bearings and the horizontal axis following the movement around the vertical axis (Fig. 17). This is the second type of goniometer. Unfortunately there is no international agreement as to which type is to be taken as standard. As a consequence, unless the type of apparatus with which the distribution was measured is specifically stated, the results may in some instances be misconstrued.

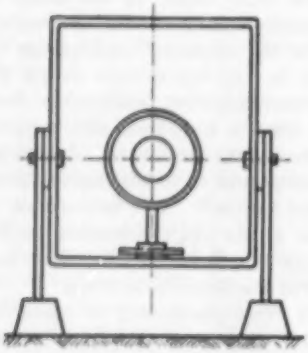

Figure 16. A measuring apparatus where the projector turns about a fixed horizontal axis and also about an axis which in the position of rest is vertical and upon rotation follows the movement of the horizontal axis.

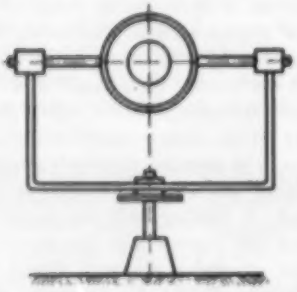

Figure 17. A measuring apparatus where the light source turns about a fixed vertical axis and also about a horizontal axis following the movement of the vertical axis.

(j) One method of determining the luminous flux in a beam is to measure the areas between isocandle curves in an isocandle diagram constructed from the candlepower measurements. In preparing such a diagram it must be remembered that the isocandle curves actually lie on a spherical surface. As long as the divergence of the beam does not exceed 5 degrees in any direction from the axis, the isocandle curves may safely be regarded as lines in a flat plane, and may be plotted as such. If the beam has a wider spread, the isocandle diagram must be projected on a flat plane. This is in essence the procedures followed by a geographer in making a map. It is not possible to project spherical figures onto a flat plane so as to give a true reproduction of both the shape and the area of the figures, but there are several methods by which a projection is obtained that gives either one or the other feature of the figure in its true dimensions. One method widely used in photometry, because it has the advantage of producing area-proportional figures, is the so-called "sinusoidal projection." By this method a point on a sphere (of radius r) with the coordinates longitude l and latitude b is determined on the flat plane by the flat coordinates:

$$x = rl\cos b,\quad y = rb$$

(k) The two types of goniometer shown in Figs. 16 and 17 produce two different sinusoidal projections, and in order to avoid errors it is necessary to differentiate clearly between them. With the apparatus shown in Fig. 16 the angle of the rotation around the horizontal axis may be regarded as longitude, and the rotation around the other axis as a movement in latitude. The poles of this system lie in the horizon in a direction perpendicular to the optical axis of the projector, and the equator passes through the zenith. As the projector is turned about the vertical axis the measuring direction describes merid-

*Sections 6.7 (i), (j), (k) and (l) are derived from an article which appeared in Vol. 9, No. 4 of *Philips Technical Review*. This was a reissue of an "Internal Technical Announcement" published in Dutch. In the English reissue errors occurred. These have been corrected in the text here in accordance with a letter from Dr. Ir. J. Bergmans of Philips in which he requested that, in this acknowledgment, the following statement would be introduced:

"One would think that the polar axis of the system of co-ordinates would have the same direction as the polar axis of rotation of the spotlight (so of the goniometer apparatus). That this is not the case becomes obvious when one realises that during measurement:

(a) the measuring direction is stationary
(b) the spotlight moves

whereas in the light distribution diagram it is supposed that

(a) the spotlight is stationary
(b) the measuring direction moves.

So also when measuring one has to consider the whole procedure as if

(a) the spotlight were stationary
(b) the measuring direction with the whole world in fixed connection with it were moving in respect to the stationary spotlight.

"Consequently the polar axis of the light distribution diagram is the axis which is *stationary with respect to the spotlight*. This happens to be the movable axis of rotation of the goniometers."

ians, and as it turns about the horizontal axis the measuring direction describes circles of latitude. Fig. 18 illustrates how these meridians and circles of latitude are represented in a sinusoidal projection. With the type of goniometer shown in Fig. 17 the rotation about the vertical axis is a movement in longitude, and the rotation about the horizontal axis is latitude. The poles coincide with the zenith and the nadir, and the equator coincides with the horizon. As the projector turns around the horizontal axis the measuring direction describes meridians, and as it turns around the vertical axis it describes circles of latitude. Fig. 19 shows the grids corresponding to the movements in this system projected sinusoidally, with some of the meridians and circles from Fig. 18 added as dotted lines for purposes of comparison.

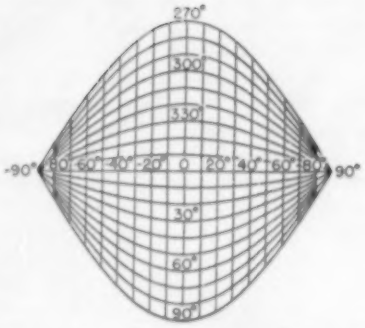

Figure 18. The sinusoidal projection of the grid belonging to the measuring apparatus of Fig. 17.

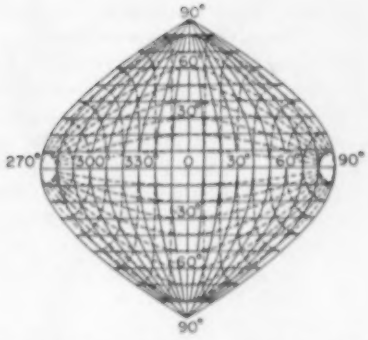

Figure 19. For comparison some meridians and small circles of Fig. 18 are shown as dotted lines on the sinusoidal projection of the grid belonging to the measuring apparatus of Fig. 16.

(l) When the beam spread is small, the type of goniometer on which the measurements were taken would have a negligible effect on the calculated luminous flux. However, where the beam spread is of the order of 20 degrees or greater, to interpret measurements taken with a Fig. 16 type goniometer as having been taken with Fig. 17 equipment would lead to a serious error. This is illustrated in Fig. 20, which reproduces on an enlarged scale the central part of the diagram of Fig. 19. It is obvious, for instance, that the bearing obtained with a Fig. 17 type goniometer at 30 degrees north and 30 degrees west (point *A* in Fig. 20) makes an angle of approximately 5 degrees with the position obtained at the same bearings with a Fig. 16 goniometer (point *B*). Obviously, then, when measuring beams with a wide divergence it is always essential to state with what type of apparatus the measurements were taken. Fig. 21 is a sinusoidal projection of an isocandle diagram plotted from candlepower measurements made with a goniometer of the type shown in Fig. 17. The total flux in this beam can be calculated by measuring with a planimeter the area between each two successive isocandle curves, and multiplying by the estimated average candlepower for that area.

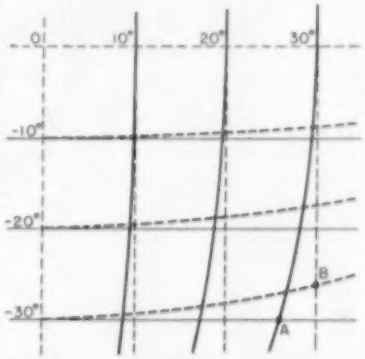

Figure 20. The middle part of the diagram illustrated in Fig. 19 on a magnified scale. The bearing indicated by 30 degrees north and 30 degrees west (point A) by means of the apparatus according to Fig. 17 makes an angle of about 5 degrees with the same bearings obtained with the apparatus of Fig. 16 (point B).

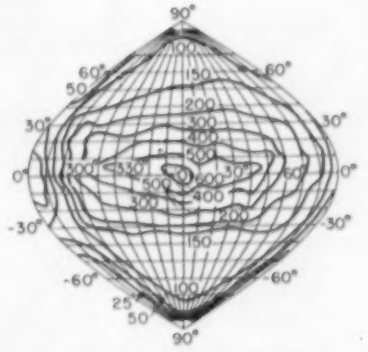

Figure 21. The iso-candle diagram of a "Cornalux" lamp in sinusoidal projection. The luminous intensity is given in candles, while the total luminous flux of this light source amounts to 1320 lumens. From the diagram it may be read that this lamp, which is used for ceiling lighting, emits its light in a rather narrow beam.

(m) The luminous flux in a beam may also be calculated directly from the candlepower measurements, without plotting an isocandle diagram. This method is similar to that described in Section 6.6 (e) for determining the flux represented by a symmetrical candlepower distribution obtained on a distribution photometer, except that here the areas are "rectangular," rather than annular. The factors by which the candlepower values are multiplied are proportional to the lune of a unit (radius) sphere included between the bounding vertical and horizontal angles of the spherical rectangles used in obtaining the distribution. The bounding angles are, of course, chosen so that there is no overlapping of the spherical rectangles. For a goniometer of Fig. 17 construction the area of the lune in an octant, included between two angles in the vertical plane perpendicular to the horizontal axis of the goniometer, is proportional to $\pi\Phi/180$, where Φ is the difference between the bounding angles of the lune. The part of a given lune included between two angles in the horizontal plane, perpendicular to the vertical axis of the goniometer, is proportional to the difference in the sines of the bounding angles (measured from the axis of the beam). The factor for any spherical rectangle then is given by $\Phi\pi/180$ $(\sin\theta_2 - \sin\theta_1)$, where Φ is the vertical angular interval and θ_1 and θ_2 are the bounding horizontal angles.

For example, if readings are taken at the midpoint of 6-degree vertical lunes and at the midpoint of 10-degree horizontal angles, the factor for the spherical rectangle corresponding to the reading at 35 degrees from the beam axis in the horizontal plane (bounding angles 30 and 40 degrees) is $6\pi/180$ (sin 40 − sin 30) or 0.014958. For a goniometer of the type shown in Fig. 16 the angles are reversed, and Φ in the formula for the factor becomes the horizontal angular interval, and θ_1 and θ_2 become the bounding vertical angles. Tables of lunal, analogous to zonal, factors for various vertical and horizontal spacings for both types of apparatus are available.[20, 23, 28] In making flux calculations by this method it is essential to distinguish between the two types of goniometer, and to be sure that the lunal factors are the correct ones for the instrument used.

6.8—*Low Brightness (Photometric)* — **(a)** In Section 2 the characteristics of the eye for the photopic, mesopic and scotopic states were discussed. All ordinary photometric measurements are assumed to be made with the observer's eye in the photopic or light-adapted state. The eye can no longer be regarded as light-adapted when the photometric brightness is much below 1,000 microlamberts. The photometric brightness of the various luminescent materials, both fluorescent and phosphorescent, is usually in the mesopic and scotopic ranges.

(b) The following are four of several ways to assign numerical values to a scale of photometric brightness below the photopic range:

(1) Arbitrary application of the photopic luminosity function to all photometric brightnesses by making visual comparison of fluorescent and phosphorescent materials only, with a standard of similar spectral composition ,the standard to be evaluated by way of the standard luminosity factors (see Section 3.7).

(2) Adoption of an arbitrary photoelectric procedure for evaluating the radiant energy from fluorescent and phosphorescent materials.

(3) Definition of the unit and scale of mesopic and scotopic photometric brightness in terms of the hypothetical equal-energy source.

(4) Definition of the unit and scale of mesopic and scotopic photometric brightness in terms of an incandescent lamp operating at some specified color temperature, such as 2353 or 2042 degrees Kelvin.[24]

(c) The standard photopic luminosity function (1) has been used in some cases. Radioactive green materials have been evaluated in this way for some years. Each material characterized by radiant energy of a new spectral composition requires the setting up and evaluation of a new standard. For various samples of the same material, the method gives useful comparisons; but because of the Purkinje effect, the photopic photometric brightnesses of two materials compared to one another do not necessarily correlate with the observable brightnesses in the mesopic and scotopic ranges of the materials.

(d) A better correlation is obtainable by arbitrary adoption of a photoelectric procedure in which the source-filter photocell (or phototube) combination is approximately equivalent to the luminosity function somewhere within the mesopic range (2). It is obvious, however, that no one luminosity function can be generally valid.

(e) Procedures (3) and (4) are similar and give values of mesopic and scotopic photometric brightness that correlate well with subjective brightness. The use (3) of the hypothetical equal-energy source would bring a unique, logical simplicity to the general concept of photometric brightness, but the predominant opinion[3] was that an incandescent filament lamp source at 2360K is more convenient in practice and, on that account, preferable for tentative standardization and use at the present time. It has been recommended at recent international meetings that the base be the platinum black body rather than 2353K.[24] By this choice the comparison source is assigned mesopic and scotopic photometric brightnesses by the same methods (inverse-square law, aperture relations, etc.) used for photopic photometric brightness.

(f) A photometer using a comparison field of color temperature 2353K and mechanical control of the photometric brightness of this field has been designed[25] and is now commercially available.

6.9—*Homochromatic*—(a) The most precise photometric comparisons are possible only when the sources being compared have identical spectral composition, in which case they emit light of the same color. When the comparison is a truly homochromatic one, any linear or calibrated device may be used, having any spectral response curve. In fact, valid comparisons can be made by using a narrow range of wavelength. Consequently, an effort should always be made to reduce any difference in spectral composition of the sources as much as possible, as, for example, by use of color matching filters.

(b) Visual photometric comparisons of sources having the same color can be made with a precision of better than ¼ of one per cent, provided a well-made equality-of-contrast Lummer-Brodhun photometer head is employed. Photoelectric and radiometric photometers can, with proper precautions, attain the same or slightly better precision. The accuracy in all photometry depends upon care in avoiding stray light, cleanliness of photometer parts, use of distances where the inverse-square law is valid, and attention to many details.

6.10—*Heterochromatic*—(a) When the eye is required to decide when equality of brightness or equality of contrast exists between comparison surfaces illuminated by sources having different spectral compositions, it encounters a difficulty which increases as the color difference becomes greater. The principal methods of heterochromatic photometry are the cascade method, the compensation method, flicker-photometer method, and the use of color-matching or color-equalizing filters.

(b) The cascade method consists of dividing up the color difference by making the photometric settings in a number of steps. When incandescent filament lamps operating at different color temperatures are to be compared, it is possible to divide the color difference into a number of steps, by using lamps operating at intermediate color temperatures.

(c) In the compensation (or mixture) method the color difference is reduced by illuminating one or both of the comparison surfaces with light from both the sources being compared. While the reduction of the color difference improves the ease with which a balance of the fields is obtained, the sensitivity is correspondingly reduced, since the photometer surfaces do not

receive light from a single source; in fact, carried to the extreme, the color difference and sensitivity vanish together.

(d) The flicker photometer is a means of heterochromatic photometry in which a single field is alternately illuminated by the sources to be compared. The observer sees a flicker, in positions of photometric unbalance, due to color difference and difference in photometric brightness. Above a certain rate of alternation (which is moderate) the color sensations blend while the flicker due to difference of photometric brightness persists and its disappearance under some observing conditions is a reliable indication of equal photometric brightness. These conditions are (1) an illumination of the field of at least 25 meter candles (about 2.3 footcandles), (2) a field size of 2 degrees diameter and (3) a background field about 25 degrees in diameter and approximately equal to the field in photometric brightness. One type of flicker photometer is really an attachment to be used with an equality-of-brightness Lummer-Brodhun cube, preferably with a quadrant pattern. This is known as the Ives-Kingsbury flicker photometer and consists of an optical path including a lens for magnifying the field, a rotating prism, an aperture to limit the field to the specified 2 degrees, a lamp to illuminate the 25-degree background and an eyepiece lens. These optical parts reduce the photometric brightness of the field and with weak sources make it impossible to obtain the specified field photometric brightness (corresponding to 25 meter candles). The Guild flicker photometer obviates this by viewing the surfaces directly; one is a stationary surface and the other a rotating quadrant-sector, disk, the stationary surface being viewed through the rotating disk. Where a large color difference exists, a flicker photometer gives results which are more consistent and dependable than those obtained by the use of the equality-of-brightness or equality-of-contrast photometers.

(e) In heterochromatic photometry observers may be tested by means of certain test solutions,[26] and the readings of a group of observers are plotted against their Y/B ratio and the value corresponding to Y/B 1.00 determined. The Y/B, yellow-blue, ratio is determined by the use of test solutions which transmit the yellow and blue portions of the spectrum.[27] The ratio is 1.00 for a color temperature of approximately 2080K (the color temperature of carbon-filament lamps), and the "normal" value for other color temperatures may be calculated from the spectral transmittances of the solutions; at 2700K, for example, the ratio would be 0.84 for the "average" observer. Observers with Y/B ratios outside the range 0.80 to 1.20 (for 2080K) may be considered to have abnormal color vision and should not take observations that are to be used in important measurements. The group of observers should have an average Y/B ratio of approximately unity, with any observers near the extremes of the normal range occurring in offsetting pairs or groups.

(f) The use of color matching or color equalizing filters reduces the measurements to a homochromatic basis and any photometer may be used. It is necessary to determine the transmittance of the filter for light of the spectral distribution of the source with which it is used. The factor for the filter can be determined by means of spectrophotometric data and the standard luminosity factors.

Section 7—General Guide to Photometry

Standards

7.1—*Primary*—**(a)** A primary standard of light is one by which the unit of light is established and from which the values of other standards are derived. A satisfactory primary standard must be reproducible from specifications.

(b) Prior to January 1, 1948, pending the development of a satisfactory primary standard, the "candle" was represented by groups of carbon-filament lamps. The values assigned to these groups resulted from agreement by the laboratories of the United States, France and Great Britain (a correlated agreement was reached on the ratio of the Hefnerkerze to the international candle) and the unit was called the international candle.

(c) On January 1, 1948, a "new candle" was established. The "new" system of photometric units takes as the primary standard a black-body radiator operated at the temperature of freezing platinum, and the unit of luminous intensity (candle) is defined as $^1/_{60}$ of the luminous intensity of one square centimeter of such a radiator.

(d) The use of the primary standard is not feasible except in a well-equipped laboratory; since the light from it is not greatly different in color from that given by carbon-filament standard lamps, such lamps will continue to be the working standards for practical photometry. Carbon-filament standards assigned values prior to January 1, 1948, may be adjusted to the new basis by increasing their numerical rating in international candles by 1.9 per cent without the necessity of recalibration. This factor applies only to lamps operating close to a color temperature of 2100K. Other types of lamps are discussed in the next section.

7.2—*Secondary*—The unit of luminous intensity at other color temperatures is to be derived from the primary standard, with the provision that when color differences are involved the evaluation shall be made by means of the standard luminosity factors[5] given in Section 3.7. When light sources of higher color temperature are compared with the basic standards — that is, the carbon-filament lamps or platinum-black-body standard — measurements in accordance with the standard luminosity factors give progressively lower values for the "whiter" sources than were obtained by visual measurements when the international units were established. The difference between

the new and international scales, consequently, grows less as the color temperature of the measured sources is increased. The two scales cross in the vicinity of 2500 K, approximately the operating color temperature of vacuum tungsten-filament lamps; furthermore, when the photometric scale was extended in range to include gas-filled tungsten-filament lamps and other modern types the methods used were nearly in accord with the standard luminosity factors. The result is that the ratings of tungsten-filament lamps and fluorescent tubes have been practically unaffected by the change. Vacuum tungsten-filament lamps have had their numerical ratings *increased* by about one-half of one per cent; gas-filled tungsten-filament lamp ratings have been *reduced* by a slightly greater amount; and fluorescent tube ratings were left unchanged.

7.3—*Working Standards*—A photometric laboratory should have calibrated lamps that are used only as reference or fundamental standards. Working standards for daily use can be measured in terms of this reference group of standards. Still other lamps for use in one test or a series of tests may be calibrated and thus conserve the useful life of the reference group and working standards.

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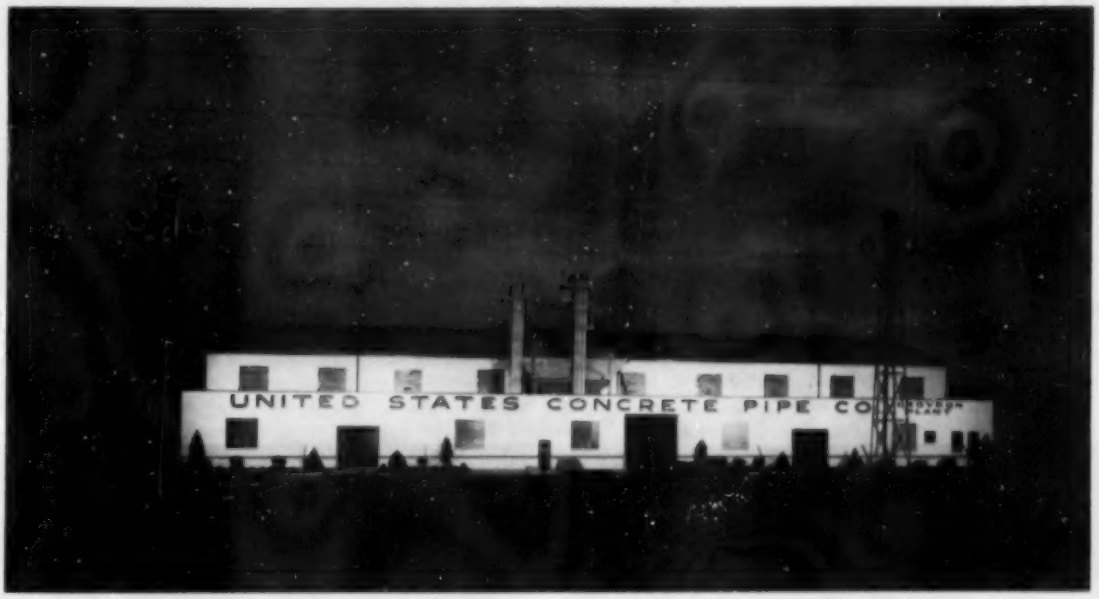
IES OFFICERS — A listing of the IES National Officers, Section and Chapter Chairmen and Secretaries, and Local Representatives for the year 1954-1955 appears on pages 34A, 36A, 39A and 40A of this issue.

COMMITTEE PERSONNEL — The Society's Standing, General, Task and Technical Committees and Subcommittees are listed, with personnel, on pages 21A, 22A, 24A, 27A, 28A, 30A, 33A.



INSTALLATION AT UNITED STATES CONCRETE PIPE COMPANY, CROYDON, PENNA.

Floodlighting an Industrial Plant

LIGHTING OBJECTIVE: To illuminate for advertising purposes the exterior of an industrial plant and sign.

GENERAL INFORMATION: This plant faces the mainline tracks of the Pennsylvania Railroad and a highway. The facade is approximately 200 feet long and 28 feet high. The letters in the sign are approximately 3 feet square with a 6-inch stroke. The letters are black and building white (80% RF).

INSTALLATION: Nine Westinghouse No. 1220546 closed floodlights containing 1000-watt PS-52 clear incandescent filaments lamps are mounted on three 28-foot high steel towers (three units per tower). The towers are 66 feet apart and 130 feet from the building. Beam-spread is 14 degrees. The resultant vertical illumination on the building face is 5 footcandles and the sign is visible 500 feet.

Lighting designed by Arthur C. Schafer, Lighting Applications Section, Philadelphia Electric Company.

Lighting data submitted by Arthur V. Schafer, Philadelphia Electric Company, as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Series XX 4-55

A.I.A. File No. 31

Here and There With I.E.S. Members

Looking from the speakers' table at the February 24 meeting of the St. Louis Section. Attendance was 96, including 30 ladies who came to hear Robert L. Coe, Residential Sales Manager of Union Electric Co. of Missouri speak on "Nine Million Opportunities."

One of the 40 high school student finalists in the 13th annual Science Talent Search discusses ultraviolet light with E. W. Beggs (left) and R. L. Zahour, Lamp Division of Westinghouse, which sponsors the competition, awarding $11,000 in scholarships to top winners.

Progress in lighting was the subject of the February 8 meeting of the Michigan Section, with T. C. Sargent, Sylvania, as guest speaker. Left to right in photo are, John Doyle, Program Chairman; T. C. Sargent, and Les Lyons. Meeting was held in the Detroit Edison Sales Auditorium.

Southern Regional V-P Glenn Park was guest of honor and speaker at the February 14 meeting of the Georgia Section, IES, speaking on the future of lighting. Left to right in the photo are: front row, J. Dixon Mitchell, past Chairman of the Section; Regional V-P Park; Judd Lough, Section Vice-Chairman; back row, W. M. Pearson, J. D. Poage, J. E. Sweatte and R. E. Lawler, who comprise the Section's Board of Managers. Photo is by Tom Haslam, member of the Georgia Section.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Report from the '55 IES Conference Committee

If you need the latest information in the field of illumination and want to meet others interested in lighting, plan now to attend the 1955 National Technical Conference. Time is September 12 through 16; place is Cleveland, Ohio. Lighting authorities from all parts of the world will be at this meeting.

The Conference Papers Committee enthusiastically reports that the papers are excellent. A large portion of the papers this year will deal with the practical application of light for both functional and esthetic purposes. More parallel sessions on lighting applications, design and installations are planned this year than ever before. Papers will be presented on Monday through Thursday. Friday is being reserved for committee meetings, which will not be held during regularly scheduled conference sessions.

Entertainment planned will be outstanding. Of course, luncheons, teas, tours, fashion shows, movies, museums, shopping, etc. will afford an interesting and busy time for the wives daytimes during the week days. On Monday evening an informal party is being planned for an IES Futurama. Sections and chapters are urged now to start developing skits built around "What Is to Come in the Year 2000." This party will be populated by people from Mars, robots, tobors, space cadets, creatures from the Black Lagoon, etc.

On Tuesday the always interesting and well attended Progress Report is scheduled. An International outdoor party will be held at Nela Park on Wednesday evening. Details of this party will be announced soon. On Thursday evening is the social highlight of the week — the banquet and dance preceded by the President's Reception.

Creating Pictures with Light, Five-Day Clinic at CLI

Ten sessions of discussions and demonstrations comprised the clinic on "Creating Pictures with Light," with two meetings each day from February 7 through February 11. The clinic this year was again sponsored by the Chicago Lighting Institute in cooperation with the Chicago Area Camera Clubs Association and the Associated Amateur Cinema Clubs. Chairman and Co-Chairman of the clinic were Clifton Hyland, Lamp Dept., General Electric Co., Chicago, and R. L. McIntyre, Editor, Camera Column of the Chicago Tribune. They also served as chairmen for some of the individual sessions, with Carl F. Jensen, Lamp Dept., Westinghouse, Chicago; Rush Munder, Sylvania Electric Products Inc., Chicago; presiding at the other sessions.

The meetings were held at noon and in

REGISTRATION was 275 at the highly successful Street Tree and Utility Conference, held March 3-4 at the Wade Park Manor, Cleveland. It was voted overwhelmingly to hold another such conference in two years. Co-Chairmen of the meeting were K. M. Reid of IES; E. H. Scanlon of the National Shade Tree Conference and J. W. Anderson of the Edison Electric Institute. Printed proceedings of the papers presented, in full and with discussion, will be available in three to four months at a cost of from five to seven dollars.

Here and There with I.E.S. Members

Professor J. O. Kraehenbuehl, University of Illinois, was the featured speaker at the February 14 meeting of the Rocky Mountain Section, with the present and future in illumination courses in universities as his topic. In photo at right, are, in the usual order, C. O. Woodworth, Section Chairman, Professor Kraehenbuehl; and Thorle Vieau, Program Committee Chairman.

Cleveland Section, I.E.S., presented "The Light of Your Life," another in a series of TV shows on the adventures in engineering and science sponsored by the Cleveland Technical Societies Council, on February 13 over station WNBK. Presenting the show are, l. to r., R. D. Burnham, Wakefield; R. L. Oetting, G-E; Ronald Springer, high school senior; Elizabeth Galambos, high school senior; W. C. Brown, G-E; A. F. Wakefield of F. W. Wakefield Brass; and Harvey E. Newman, Westinghouse. The IES Coordinating Committee for the show was W. H. Kahler, Westinghouse; R. W. Mausk, Cleveland Electric Illuminating Co., and Horace G. Schiller, G-E Co., Chairman.

Annual joint meeting of the Southern California Section of I.E.S. with the American Institute of Electrical Engineers, February 8, drew an attendance of 145 to hear speakers, Dr. Henry A. Knoll, Dean of Los Angeles College of Optometry, and Don P. Caverly, Sylvania Electric Products, Inc. Meeting was held at the Friday Morning Club.

the evening, and subjects and speakers were:

Monday

Stereo Photography — A. T. Lewis, Realist, Inc., Milwaukee, Wis., assisted by Stanley Parks.

Making Medical Movies — Marvin La Rue, Marvin La Rue, Inc., Chicago.

Tuesday

How to Use the Color Exposure Meter — C. K. Ainsworth, General Electric Co., Lynn, Mass.

Printon in the Camera—Raymond Tourangeau, Ansco Corp., Chicago.

Functions of Chicago's Crime Photo Laboratory — Lieut. John Ascher, Director of the Chicago Police Dept. Crime Laboratory.

Wednesday

Producing the Photo Mural — Julious Hoffman, Kauffman and Fabry, Chicago.

Printon in the Camera—Raymond Tourangeau, Ansco Corp., Chicago.

Thursday

Making the Esquire Magazine Cover (Table-Top Photography) — Jules Friedlander, W. F. Hall Printing Co., Chicago, and Photo and Graphic Arts Consultant for Esquire Magazine.

Color Illustrations—Dick Boyer, Director, Dick Boyer Studios, Chicago, with Models by Patricia Vance Modelling Agency.

The New Kodak Ektachrome Film — F. E. Johnson, Eastman Kodak Co., Rochester, N. Y.

Friday

Speedlighting the Subject — George Ward, Heiland Division, Minneapolis Honeywell Corp., Minneapolis, Minn.

Photography with Low Level Illumination — F. E. Johnson, Eastman Kodak Co., Rochester, N. Y.

Transmitting Wirephoto Pictures — Fred E. Francis, Traffic Chief, the Associated Press, and Fred Wright, Picture Editor for AP.

There was no admission fee for the clinic, which was held at the Chicago Lighting Institute, Carl Zersen, Managing Director. Frank R. Kuper is President of the Chicago Area Camera Clubs Association, and Cyril S. Dvorak of the Associated Amateur Cinema Clubs.

Modern School Lighting — Subject Of Pittsburgh Symposium

A panel discussion of modern school lighting by four experts was the subject of the symposium held March 18 by the Pittsburgh Section of IES, each panel member discussing a different aspect of the topic. Speakers were:

Thomas C. Pratt, AIA, who, as a partner in Ingram, Boyd and Pratt, has designed the schools of many of the townships in the Pittsburgh area. Mr. Pratt discussed appearance, color, fixture selection, and quantity and quality of illumination.

Lawrence W. Hornfeck, PE, who is an electrical consultant retained by the Pittsburgh School Board and others, presented the role of the Professional Engineer: wiring, types of systems, fixtures, footcandles.

Leo R. Travis, superintendent of the McKeesport School District, was instru-

(*Continued on page* 11A)

LIGHTING CALENDAR

Society Events

April 11-13, 1955 — Inter Mountain Regional Conference, Westward Ho Hotel, Phoenix, Arizona.

April 13-15, 1955 — South Pacific Coast Regional Conference, Statler Hotel, Los Angeles, Calif.

April 25-26, 1955 — Pacific Northwest Regional Conference, Harrison Hot Springs Hotel, Harrison Lake, B. C.

May 2-3, 1955 — Midwestern Regional Conference, Edgewater Beach Hotel, Chicago, Ill.

May 12-13, 1955 — Canadian Regional Conference, Hotel Mount Royal, Montreal, Que.

May 19-20, 1955 — East Central Regional Conference, Abraham Lincoln Hotel, Reading, Pa.

June 9, 1955—Meeting of I.E.S. Council, Lake George, New York.

June 10-11, 1955 — Northeastern Regional Conference, Ft. William Henry Hotel, Lake George, N. Y.

September 12-16, 1955 — Illuminating Engineering Society, National Technical Conference, Hotel Statler, Cleveland, Ohio.

Industry Events

April 13-15, 1955—American Institute of Electrical Engineers, Southern District, Soreno Hotel, St. Petersburg, Fla.

April 17-22, 1955 — Society of Motion Picture and Television Engineers, 77th Semi-annual Convention, The Drake Hotel, Chicago, Ill.

April 18-21, 1955 — The American Society of Mechanical Engineers, Spring Meeting, Lord Baltimore Hotel, Baltimore, Md.

April 25-27, 1955 — National Association of Lighting Maintenance Contractors, Annual Conference, Henry Grady Hotel, Atlanta, Ga.

May 4-6, 1955—American Institute of Electrical Engineers, Middle Eastern District, Deshler-Hilton Hotel, Columbus, Ohio.

May 10-12, 1955 — Chicago Electrical Industry Show, Conrad Hilton Hotel, Chicago, Ill.

May 11-13, 1955 — Pacific Coast Electrical Association, Inc., Annual Convention, Palace Hotel, San Francisco, Calif.

May 12-13, 1955 — Public Utilities Advertising Association, Annual National Convention, Sheraton Hotel, Chicago, Ill.

May 22-25, 1955 — National Association Electrical Distributors, 47th Annual Convention, Conrad Hilton Hotel, Chicago, Ill.

June 12-15, 1955 — Western Plant Maintenance and Engineering Show, Pan Pacific Auditorium, Los Angeles, Calif.

June 13-16, 1955 — Edison Electric Institute, Annual Convention, Los Angeles, Calif.

June 13-22, 1955 — International Commission on Illumination (CIE), 13th Session, Zurich, Switzerland.

June 20-24, 1955 — American Society for Engineering Education, Pennsylvania State University, State College, Pa.

June 26 - July 1, 1955 — American Society for Testing Materials, 58th Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

June 27 - July 1, 1955 — American Institute of Electrical Engineers, Summer General Meeting, New Ocean House, Swampscott, Mass.

August 15-19, 1955 — American Institute of Electrical Engineers, Pacific General Meeting, Butte, Montana.

September 25-28, 1955 — National Association of Electrical Distributors, Annual Convention, Pacific Zone, Empress Hotel, Victoria, B. C.

September 27-29, 1955 — Electrical Progress Show, Convention Hall, Philadelphia, Pa.

October 1, 1955 (Tentative) — Institute of Traffic Engineers, 26th Annual Meeting, Pittsburgh, Pa.

October 3-5, 1955—National Electronics Conference, Hotel Sherman, Chicago, Ill.

October 3-7, 1955 — Society of Motion Picture and Television Engineers, 78th Semi-annual Convention, Lake Placid Club, Essex County, N. Y.

October 3-7, 1955 — American Institute of Electrical Engineers (Fall General Meeting), Morrison Hotel, Chicago, Ill.

October 5-7, 1955 — Canadian Electrical Manufacturers Association (11th Annual Meeting), Sheraton-Brock Hotel, Niagara Falls, Ontario, Canada.

October 11-14, 1955 — National Electrical Industries Show, 69th Regiment Armory, New York, N. Y.

October 17-21, 1955 — National Safety Council, 43rd National Safety Congress & Exposition, Chicago, Ill.

October 24-26, 1955 — 37th Annual Meeting and Sixth National Conference on Standards, American Standards Association, Washington, D. C.

October 30, 1955—Week of—National Electrical Contractors Association, Waldorf-Astoria, New York, N. Y.

November 1-3, 1955 — Fifth Industrial Electric Exposition, Hotel Wm. Penn, Pittsburgh, Pa.

November 2-5, 1955 — National Electrical Contractors Association, Annual Convention, Waldorf-Astoria Hotel, New York, N. Y.

November 14-18, 1955 — National Electrical Manufacturers Association, Annual Meeting, Traymore Hotel, Atlantic City, N. J.

November 14-18, 1955 — Chicago Exposition & Power and Mechanical Engineers ASME Chicago Coliseum, Chicago, Ill.

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I.E.S. Regional Conferences — 1955

Pacific Northwest	Harrison Hot Springs Hotel Harrison Lake, British Columbia	April 25-27
Midwestern	Edgewater Beach Hotel Chicago, Illinois	May 2-3
Canadian	Mount Royal Hotel Montreal, Quebec	May 12-13
East Central	Abraham Lincoln Hotel Reading, Pennsylvania	May 19-20
Northeastern	Fort William Henry Hotel Lake George, New York	June 10-11

mental in starting the planned program of re-lighting in the McKeesport schools. Dr. Travis spoke on the physiological and psychological values, installation costs, operation and maintenance.

Harry W. Stone, RA, has designed numerous school buildings and is now the chief of the School Plant Division, Department of Public Education, approving construction of all Pennsylvania schools. As educator and architect, he spoke on the school code — new and old, costs, methods and benefits realized.

Technical Report Writing Workshop To Be Held at Penn State

Increased scientific specialization has magnified the importance of technical reports as the end product of practically all research and development organizations, say engineering experts of Pennsylvania State University. To help meet this need, the University is offering a two-week technical report writing workshop, August 1-12, on the main campus in State College, Pa. On the premise that technically trained people must master the tools of composition to translate the results of their work into reports readily understood by administrators and technical specialists, the course will aim at giving practical instruction and supervised practice necessary to produce effective reports.

Some of the topics to be discussed are characteristics of good technical writing; methods to achieve these characteristics; a brief review of grammar; practical report writing assignments; use and misuse of mechanical aids; and the differences among various kinds of reports.

The course is being offered by the University's College of Engineering and Architecture, under the direction of Dr. Dwight E. Gray, Technical Information Division, the Library of Congress. For further details write to General Extension, The Pennsylvania State University, University Park, Pa.

Regional V-P Presents Central Oklahoma Chapter Charter

Charter night for the Central Oklahoma Chapter of I.E.S. was March 8, with an attendance of 31 members and guests. After a business meeting at which the By-Laws of the Chapter were accepted, and officers elected, Chairman Elmer Prag read a telegram of congratulations from National Vice-President M. N. Waterman.

Highlights of the evening were the presentations of the Chapter's gavel and Charter, with John S. Williams, Chairman of the next-youngest Arkansas Chapter, presenting the gavel. Regional V-P of the Southwestern Region, M. J. Myers then handed the Chapter's Charter to its Chairman and gave a talk on the Past, Present and Future of the Illuminating Engineering Society.

EEI Sales Conference Held in Chicago

The 21st annual sales conference of Edison Electric Institute was held March 28-31 at the Edgewater Beach Hotel, Chicago.

The Monday session was a full day Home Service Meeting with discussion on ways the Home Service can cooperate to sell electricity, and the merits of group and home calls.

The Tuesday meeting consisted of four concurrent sectional sessions covering the four major markets — commercial, farm, industrial and residential.

The General Sessions, convening on Wednesday morning and carrying through Thursday morning, included prominent speakers from the electrical and allied industries, such as Harold Quinton, President of Southern California Edison Co., and EEI President; Ralph Cordiner, President of General Electric; Philip Sporn, President of American Gas and Electric Service Corp., Philip A. Fleger, Chairman of the Board of Duquesne Light Co. Dr. Jules Backman of New York University; Fred Smith, Vice-President of

(Continued on page 12A)

REGIONAL V-P M. J. Myers presents the Charter of the new Central Oklahoma Chapter to its Chairman, Elmer Prag. The gavel was presented by John S. Williams, Chairman of the Arkansas Chapter. Other out-of-Chapter guests were William E. Short, Chairman of the Oil Capital Chapter and Roy Walters of Tulsa.

(Continued from page 11A)

the Gruen Watch Co., and J. C. Doyle, Sales Manager of Ford Motor Co., discussed the more general topics of selling and economic outlook.

Engineering Fellowships Established at Stevens Institute

Dr. Jess H. Davis, president of Stevens Institute of Technology has announced the establishment of the Robert Crooks Stanley Fellowships in engineering and science at the Hoboken, N .J. college. The fellowships will be awarded to full-time graduate students working for their master's or doctor's degree. The fund, which will eventually total $250,000, and the awards will be administered by a committee consisting of one faculty member, two trustees, one alumnus and three members-at-large.

The fund is a gift of the family of the late Robert Crooks Stanley, a Stevens graduate of the class of 1899 and former chairman of the engineering school's board of trustees. At the time of his death, in February 1951, Mr. Stanley was chairman of the board of the International Nickel Co.

Prizes Awarded in Oklahoma Contractors' Contest

Winning entries have been named in the commercial re-lighting contest, conducted by the Oklahoma Gas and Electric Co., from May 1954 to February 1955. During this period electrical contractors of the metropolitan Oklahoma City area submitted a total of 38 re-modeling and re-lighting installations.

The contest was divided into two sections. Members of the National Electrical Contractors Association competed for one of the two prizes, while all other contractors and members of the Independent Contractors Association tried for the other award.

Winner in the NECA group was Kerr's Department Store, second floor, installed by Oklahoma Electric Supply and designed by George Beaston of New York. The ICA winner was the Mardi Gras Room of Glenn's Hic'ry Inn, which was completed by the A. L. Nott Electric Co. and designed by Sorey, Hill and Sorey.

Eight other entries received an honorable mention from the judges, who were M. J. Myers, IES Southwestern Regional V-P, Public Service Co. of Oklahoma; Professor Joe E. Smay, Department of Architecture, Oklahoma University; and Professor Glenn H. Bryant, Department of Electrical Engineering, Oklahoma A & M College.

Paper Maker Issues Store Lighting Booklet

Modern lighting for retail food stores is the subject of a booklet devised by the Scott Paper Co., Chester, Pa., as part of the Scott Store Advisory Service. The booklet's purpose is primarily to stimulate interest in the benefits of good store lighting, with suggestions on how much light is needed, how fluorescent and incandescent lighting can be combined for best results and how colored lights can add product appeal. Representative lighting layout plans are shown, and a simple test for the store operator's use in gauging the effectiveness of his present lighting arrangement. Free copies of the booklet are available from the Public Relations Department, Scott Paper Co., Chester, Pa.

Color TV Lighting Discussed At Nela Park Conferences

The latest techniques of lighting for color television were the outstanding feature of the two two-day TV Studio Lighting Conferences held in General Electric Lighting Lighting Institute at Nela Park, Cleveland, April 4-7. More than 150 TV station managers, operators and directors from various parts of the country attended the twin programs. Each of the two "clinics" was devoted to the fundamentals of black-and-white and color TV, and to numerous associated studio lighting problems and their solutions. Discussions and demonstrations were presented by both G-E lighting specialists and speakers from TV stations.

The clinics were conducted in a model demonstration studio with a 65,000-watt connectable lighting load. The lighting equipment required was concentrated into 600 square feet of the "studio" stage.

Both black-and-white and color TV cameras were used to take pictures of the actual lighting situations. The situations were designed to permit the audience to compare the relative values of the lighted sets with the pictures appearing simultaneously on the receiver screens.

Among the topics on the first day's program were: lighting terms and lighting tools; sources for TV; color characteristics, lighting output control and circuit requirements; transfer characteristics of current camera tubes, color response and tolerable brightness ranges; TV camera adjustments for a wide range of scene brightness; and accurate rendering of color brightness.

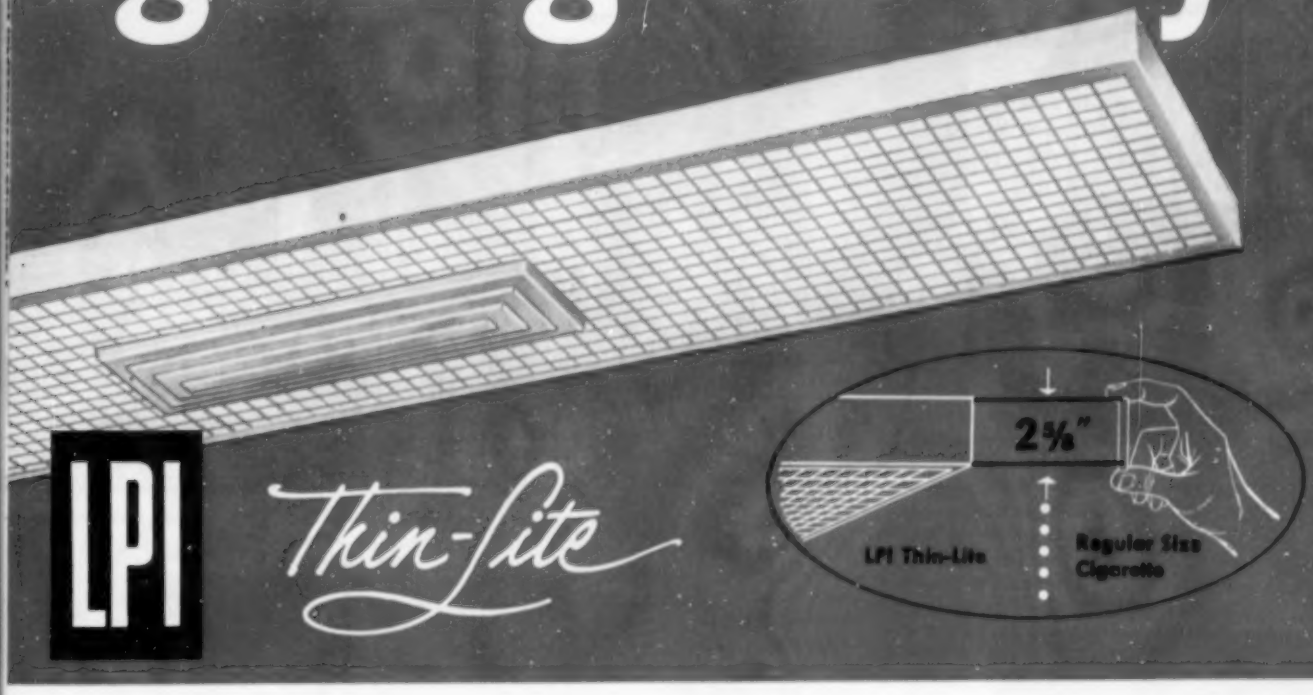
The morning of the second day was devoted, in part, to: lighting techniques for black and white pictures with three-dimensional quality; power distribution

(Continued on page 15A)

WINNING entries in the two sections of the commercial relighting contest sponsored by Oklahoma Gas & Electric Co. At left is the second floor of Kerr's Department Store, first prize in the NECA group; at right is the Mardi Gras Room of Glenn's Hic'ry Inn, which was awarded first place in the independent contractors' section.

It's making

lighting history!



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World's Thinnest Shielded Luminaire

No wonder Thin-Lite is creating such a sensation from coast to coast. Here, at last, is a surface mounted fixture so shallow that its depth below ceiling is essentially the same as that of troffers fitted with dished shields. Thin-Lite actually creates a semi-recessed effect.

The four different models (right) can be mounted end to end or side by side, in any combination, to form an unlimited variety of lighting patterns up to any desired size. A few suggestions are shown below.

Thin-Lite luminaires feature metal-framed, molded plastic louver panels, secured by LPI's patented floating hinge which cannot be seen from any angle, and which eliminates unsightly latches and fastening devices.

Available through leading electrical wholesalers, Thin-Lite luminaires are wired with standard E.T.L. ballasts.

THR 240—49" long, 12¼" wide, 2⅝" thin. Two 48" Rapid Start lamps.

THS 296—97" long, 12¼" wide, 2⅝" thin. Two 96" 430 MA. lamps.

THR 440—49" long, 26¾" wide, 2⅝" thin. Four 48" Rapid Start lamps.

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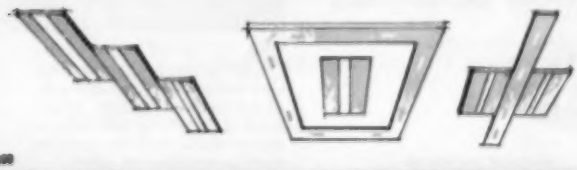

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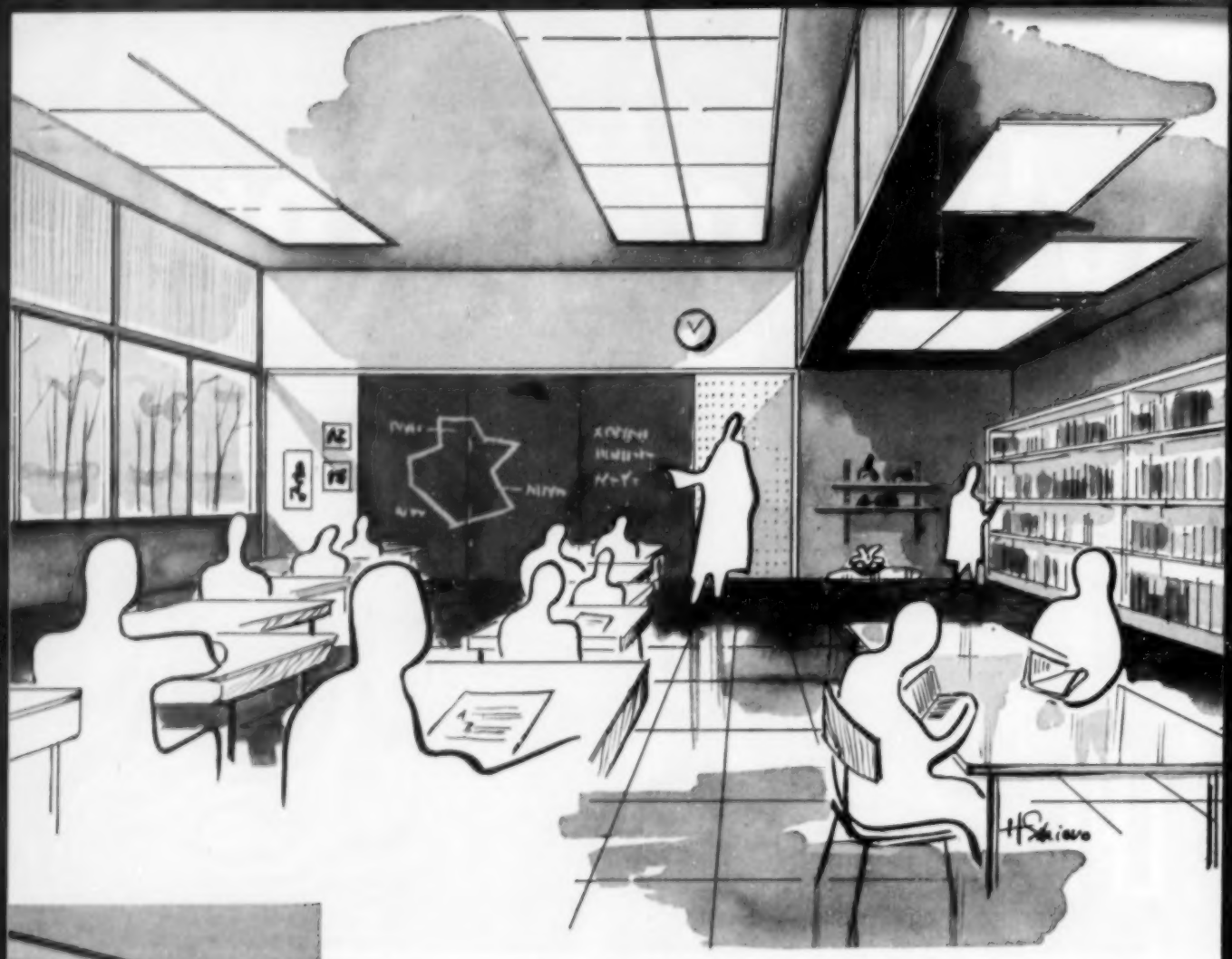

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More pleasant, more effective lighting with fixtures of extruded Du Pont LUCITE® acrylic resin

What makes a balanced, economically lighted environment? Diffusing luminaires must transmit optimum light without specular glare or shadow. Panels and sheetings need the shapes and colors to harmonize with wall, furniture and floor designs. And these fixtures should have the properties to assure long, trouble-free service.

Du Pont "Lucite" meets all these requirements. Modular units and sheeting of extruded "Lucite" have high lumen output while virtually eliminating glare and shadow. "Lucite" can be formed readily into desired shapes and is available in a wide range of transparent and translucent colors. Fixtures made from "Lucite" are strong, durable, free from discoloration and dimensionally stable . . . maintain their efficiency and beauty for many years.

For further information on "Lucite" acrylic resin, write to E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room 284, Du Pont Building, Wilmington 98, Delaware.

Good Lighting Is Good Business

Fixtures of "Lucite" acrylic resin are lightweight for easy assembly. They resist discoloration. Even broad sections are readily fabricated to precise tolerances. Above is the popular 4' x 4' modular unit.

This corrugated panel, widely used for light-diffusing walls and ceilings, has great strength, excellent color stability. Beautiful "Lucite" can be made in many sizes—and in clear as well as translucent colors.

DU PONT

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BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY

(Continued from page 12A)

recommendations for studios of various sizes, and lamp quality.

Climaxing each of the two-day conferences were the sessions devoted to progress in color television, scheduled for the final afternoon of each studio clinic. At that time, many phases of color TV were covered by the guest speakers who came to the conference from the several TV stations.

Serving as chairmen of the clinics were Frank E. Carlson and Richard Blount of the Application Engineering staff at Nela Park.

Electrical Exposition Scheduled With NECA Conference

The first National Electrical Exposition will be held October 31 through November 2 in conjunction with the 54th Anniversary Convention of the National Electrical Contractors Association. The exhibit, the first to be held at an NECA convention in almost 20 years, will feature developments in electrical materials, equipment and apparatus used by contractors for applications in lighting, heating and power, in construction and modernization for the home, factory, store, school, public buildings, hospitals, marine and public works.

West Coast Fire Destroys Leadlight Plant

One of the most spectacular aspects of the fire which completely destroyed the Leadlight fixture plant in Oakland, Calif., this winter, was the speed with which the company resumed full operation. Three weeks after the four-alarm blaze production was in full swing under temporary leases elsewhere, and plans were laid for a new building on the same site as the burned-out plant. The company's president, Milt Kosman, and his staff salvaged soggy records, blueprints and drawings while the blaze still raged, and the ashes were scarcely cooled when they leased new space and ordered new equipment to carry on immediate manufacture. A new structure is scheduled to be open soon at the same location in Oakland.

IT SEEMS TO ME

To Spur Student Interest In Illuminating Engineering

If there has been any reaction to my suggestion in "It Seems to Me" in July 1954 IE, about an educational library subscription arrangement whereby copies of IE might be placed in the science libraries of high schools by industry companies, it has not come to my attention.

I was reminded of this matter recently when, at the University of Illinois, I learned that there were only five seniors taking the Illumination Option. Some of these had taken it upon themselves to "promote" the course and as a result there are thirteen juniors. The reason for the small registration? No one seems to have any idea as to what illuminating engineering is and whether it is important. It happens that there are about as many members of IES as of AIA, but note the great difference in the number of students in training for the two fields.

I asked Professor Horn why this situation exists and he replied that students leave high school without any knowledge that there is such a thing as illuminating engineering. There is a great interest in electronics, even as compared with power, largely because of its glamor and newness *and because both the students and their high school teachers have known more about this field.*

I doubt if even our IES members realize what training those in the illumination option receive. I understand these students take the power courses planned for majors in electronics and the electronics courses planned for those majoring in power, and in addition they take courses in sales and in psychology, all in addition of course to the work in illumination. Thus they are well grounded in the fundamentals needed as application and research illuminating engineers and also for the management and administrative work likely to follow this. It is, therefore, particularly unfortunate that entering students have so little comprehension of the possibilities in this field —a situation my suggestion was intended to help.

Whether the educational library subscription idea is adopted or not, it seems to me that our Society members should do something to correct this situation, not only in behalf of college students but to acquaint all high school students with the fact that there is such a thing as illuminating engineering. At a recent "press luncheon" of high school editors to promote a career conference, these editors were amazed to learn that a profession could exist based on lighting. In a large city high school, only two students showed any interest whatever in learning about such a career. LEONARD V. JAMES, *Illuminating Engineering Consultant, 515 South Catherine Ave., La Grange, Ill.*

Photo by Joe Mahaney, Oakland, Calif.

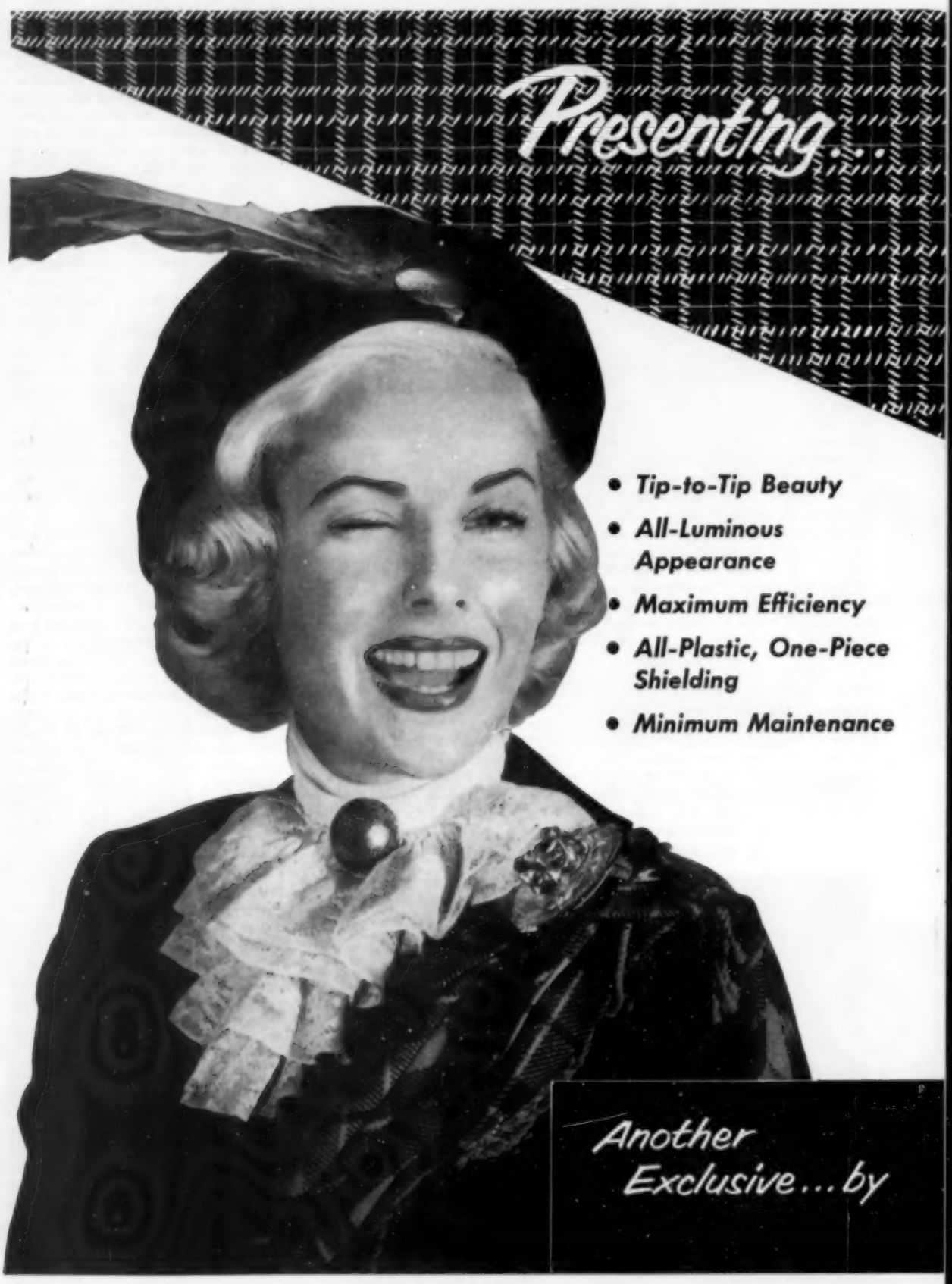
FIRE! On-the-spot photo of the Leadlight plant as flames shot 400 feet into the air and fire-fighters battled to control the raging blaze.

ABOUT PEOPLE

Don G. Mitchell, Chairman of the Board of Sylvania Electric Products Inc., has also been elected President of the company to fill the vacancy caused by the recent death of **H. Ward Zimmer**. Mr. Mitchell will serve in the dual capacity for an indefinite period, the announcement stated.

Selection of management personnel for the newly organized Miniature Lamp Department of General Electric's Lamp Division has been announced by **Kenneth G. Reider**, general manager of the department. Under the new organization, the miniature lamp business will be completely independent of both the large and photo lamp operations. National headquarters will be at Nela

(Continued on page 18A)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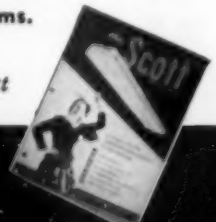

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(Continued from page 15A)

Park. Managers reporting to Mr. Reider will be: Marketing, **William H. Robinson, Jr.**; Engineering, **Walter J. Geiger**; Manufacturing, **Thomas M. Wallace**, Employee and Plant Community Relations, **Stanley W. Ross.**

In Marketing, reporting to Mr. Robinson, will be a sales manager, **Gomer F. Davis**; product planning manager, **Val J. Roper**; and the managers of eight sales districts. Sales districts and their managers will be: Atlantic, New York, **Everett G. Agee**; Midland, Chicago, **Ronald M. Pearce**; Motor City, Detroit, **John W. Fleischer**; Dixie, Atlanta, **Robert E. Lawler**; East Central, Cincinnati, **Clarence T. Niesen**; West Central, Kansas City, Mo., **Leslie O. Reed**; West Coast, Los Angeles, **Edgar E. Coleman**; and Appalachian, Philadelphia, **Robert L. Busey.**

Responsible to the manager of manufacturing will be the managers of six plants: East Boston Lamp Plant, **C. Fred Roda**; Euclid Lamp Plant, Cleveland, **Erwin E. Lehmann**; Lexington, Ky., Lamp Plant, **Ashton D. Dixon**; Memphis, Tenn., Lamp Plant, **Daniel M. Mulholland**; Seaboard Lamp Plant, Newark, N. J., **Walter D. Scannell**; and Trumbull Lamp Plant, Warren, Ohio, **Wallace E. MacLaren.**

Key positions in the newly formed Photo Lamp Department of General Electric's Lamp Division have also been filled, as announced by **William E. Davidson**, department general manager. The Photo Lamp Department, which will be responsible for the development, production and marketing of photographic lamps of all kinds, will have its headquarters at Nela Park, and will operate three existing factories and six new sales districts.

Reporting to the general manager will be a marketing manager, **Oliver H. Young**; an engineering manager, **Conrad E. Bechard**; a manufacturing engineering manager, **Wayne D. Wells**; and a finance manager, **Walter S. Glover.**

Mr. Young will have an organization including a sales manager, **Lester W. Dettman**; a marketing administrative specialist, **Robert M. Falls**; a product planning specialist, **David A. Pritchard**; and the managers of six new sales districts: Eastern, **Robert D. Jordan**, New York City; Great Lakes, **Sidney L. Fogleson**, Cleveland; Southern, **J. W. Billings**, Atlanta; Central, **Earl L. Auld**, Chicago; Mid-States, **Michael C. Finn**, St. Louis; and Western, **Louis H. Hruby**, Los Angeles.

Manufacturing plants and their managers will be: Mattoon, Ill., plant, **Walter W. Miller**; Bellevue, Ohio, plant, **Donald J. Mayer**; and East Cleveland, Ohio plant, **William B. Gillen.**

Appointment of **Jackson B. Holden** as treasury manager for Westinghouse Electric Corp. consumer products group has been announced. Mr. Holden will be located at the company's electric appliance division headquarters in Mansfield, Ohio.

Richard G. Slauer has been appointed engineering manager of technical products of the Lighting Division of Sylvania Electric Products Inc. He will have engineering and sales responsibility for the electroluminescent, infrared, mercury vapor and other special lighting products. Prior to this new assignment, Mr. Slauer was manager of the company's lighting applications laboratory.

Sola Electric Co., Chicago, announces the appointment of **Nelson P. Marshall**, formerly manager of Eastern Division Sales, as General Sales Manager. Former Western Division Manager **Pat J. Morrisey** has been named to the post of Field Sales Manager for Sola.

J. Roland Morin has been appointed head of fluorescent lamp engineering by Sylvania Electric Products, Inc. Mr. Morin, who for the past two years has been with the company's Lighting Division's general engineering department in Salem, will have his new headquarters at the Danvers, Mass., plant.

Martin R. King has been appointed manager of advertising for General Electric's Lamp Division, at the Nela Park headquarters. Mr. King was formerly at the company's administrative office in New York City, where for the past year he has been in charge of the public relations manpower development program.

Edward J. Bennan has been elected president and **Louis J. Cross** chairman of the board of Jefferson Electric Co. by the directors at a special meeting. The action followed the accidental death, February 10, of **James M. Bennan**, chairman and president of the company.

Frank J. Healy, a vice-president of Sylvania Electric Products Inc., has been elected a Director of the company. A member of the Sylvania organization and predecessor companies for the past 38 years, Mr. Healy has since 1953 been Vice-President of Operations with responsibility for the Lighting Division.

The appointment of **C. Howard Black** as general manager of the Construction Material Division of General Electric, in Bridgeport, Conn., has been announced. Until this present assignment, Mr. Black has been general manager of the company's Instrument department at Lynn, Mass. He succeeds **Clarence C. Walker** who has been named commercial vice-president for the West Coast Region with offices in San Francisco.

A. A. Aronson, Supervisor of Lighting Sales, St. Paul Division, Northern States Power Co., has assumed new duties in the Minneapolis office of his company. He has been appointed to the newly-created position of Manager, Trade Cooperation, and will be responsible for the development and coordination of all cooperative sales promotion and sales training programs. Mr. Aronson is Secretary-Treasurer of the Twin City Section of I.E.S.

Kenneth E. Fairbanks has been awarded the senior Holophane Company Illuminating Engineering Scholarship at the University of Illinois for the Fall Semester of 1954-1955, as a first semester senior. Mr. Fairbanks, who has an illuminating engineering option in the Department of Electrical Engineering, was the recipient last year of the junior Holophane Company scholarship.

Promotion of **Bruce Robertson** from sales analyst to the new position of manager of marketing research of Jefferson Electric Co., Bellwood, Ill., has been announced. The company has also

(Continued on page 48A)

I.E.S. National Technical Conferences

1955 — September 12-16 — Hotel Statler, Cleveland, Ohio

1956 — September 17-21 — Hotel Statler, Boston, Massachusetts

1957 — September 9-13 — Biltmore Hotel, Atlanta, Georgia

1958 — August 17-22 — Royal York Hotel, Toronto, Ontario

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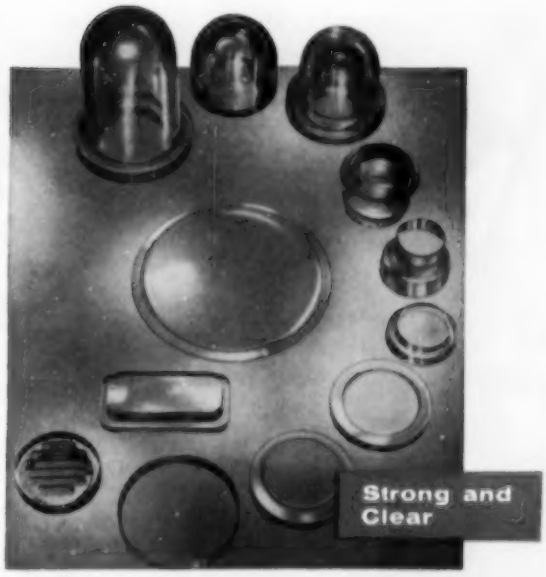

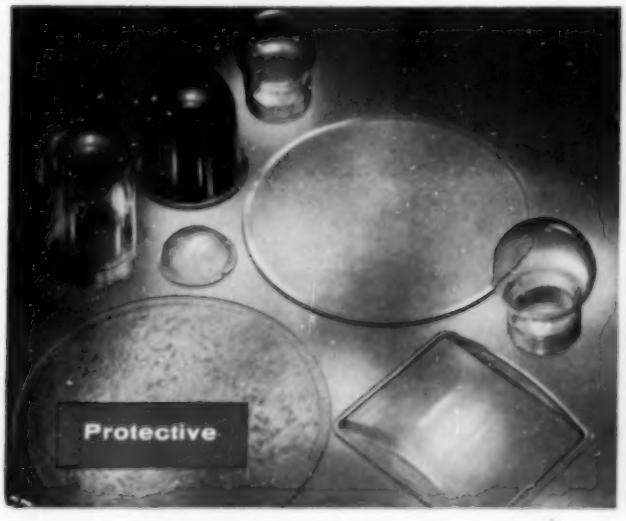

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COMMITTEES

COMMITTEES 1954-1955

All committees are appointed by the President, subject to approval of the Council and, except as provided in the Constitution, terminate at the time of the first Council Meeing each administration, in the month of October. The scope of each committee is indicated.

Duncan M. Jones, President, ex-officio member of all committees.

STANDING COMMITTEES

BOARD OF FELLOWS — To evaluate the eligibility of candidates for transfer to grade of Fellow according to procedures approved by the Council.

H. L. Logan, Chairman, Holophane Co., Inc., 342 Madison Ave., New York 17, N. Y

R. M. Evans	S. G. Hibben
W. V. C. Foulke	J. M. Ketch
	R. M. Love

COUNCIL EXECUTIVE — To conduct the affairs of the Society between Council meetings.

Duncan M. Jones, Chairman, Curtis Lighting of Canada, Ltd., 991 St. Antoine St., Montreal, Que., Canada.

R. F. Hartenstein	G. J. Taylor
K. M. Reid	M. N. Waterman

FINANCE — To have direct supervision of the financial affairs of the Society and to present to the Council an annual report on its financial condition. To make recommendations to the Council as to the investment of moneys and upon all specific appropriations. To prepare and submit for approval of Council not later than the October meeting a budget of income and expense for the ensuing fiscal year.

W. W. Booth, Chairman, General Electric Co., 1260 Boston Ave., Bridgeport, Conn.

D. P. Caverly	C. C. Keller
P. H. Hildebrand	G. J. Taylor, ex-officio

GENERAL BOARD OF EXAMINERS — To investigate the qualifications of all applicants for admission to membership; to elect or reject applicants for the grade of Associate Member and Student Member, to report such action to the Council; and to make recommendation to the Council regarding applications for transfer or election to the grade of Member and for transfer to the grade of Member Emeritus.

Clifford Miller, Chairman, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York 3, N. Y.

Svend Bruun	H. E. D'Andrade

MEDAL AWARD — To evaluate the eligibility of candidates for award of the I.E.S. Medal according to procedures approved by the Council.

George Crampton, Chairman, Lenox Instrument Co., 2010 Chancellor, Philadelphia, Pa.

Berlon Cooper	B. J. Jensen
G. F. Dean	A. H. Manwaring
C. H. Goddard	E. M. Strong
Ward Harrison	Walter Sturrock

PAPERS — To procure, review and approve all technical papers and discussions thereof, for presentation before National Conferences of the Society.

R. M. Zabel, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

H. F. Davidson, Vice-Chairman, Hydro-Electric Power Comm. of Ontario, 620 University Ave., Toronto, Ont.

L. E. Barbrow	W. P. Lowell, Jr.
L. J. Buttolph	J. A. Schneller
C. D. Fawcett	G. A. Trosper
B. F. Greene	H. L. Wright

PUBLICATIONS — To be responsible for the procurement, review and approval of all material for the publications of the Society other than technical papers approved by the Papers Committee for presentation at National Conferences of the Society and their discussions and committee reports, for which it will have publication responsibility only. Shall also be responsible for the editing, printing and business management of the publications of the Society; specific exceptions may be made by Council.

J. S. Schuchert, Chairman, Duquesne Light Co., 435 Sixth Ave., Pittsburgh, Pa.

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H. G. Clum	J. A. Schneller
Aileen M. Page	R. M. Zabel

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Home Lighting Data Sheets

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Marian Amabary	Jan Reynolds
Melrose Franklin	Ruth Schmoll
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GENERAL COMMITTEES

ADVANCE PLANNING—To study the operation, program, publication activities, membership classifications and financial structure with a view of its immediate and long-range objectives and to make recommendations to Council.

E. M. Strong, Chairman, Cornell University, Ithaca, N. Y.

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A. H. Clarke	C. C. Keller
L. S. Cooke	J. F. Whitehead, Jr.
B. J. Jensen	Robert Wiseman
	R. M. Zabel

ADVISORY BOARD ON COMMITTEE PERSONNEL — To examine the organization, accomplishments, and assignments of committees and prepare not later than July 1st of each year a proposed list of committees and personnel.

R. F. Hartenstein, Chairman, Ohio Edison Co., Akron, Ohio.

G. W. Beals	A. H. Manwaring
C. L. Crouch	E. M. Strong
A. D. Hinckley	M. N. Waterman

BOARD OF NOMINATION — To prepare a nomination ticket containing the names of those who are deemed best suited to serve as officers and directors in positions to be filled at the ensuing election

S. G. Hibben, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.
A. H. Manwaring — E. M. Strong
and Regional Representatives

CONSTITUTION AND BY-LAWS — To prepare for Council proposed amendments to the Constitution.

G. F. Dean, Chairman, Toronto Hydro-Electric System, 14 Carlton St., Toronto, Ont.

J. B. Browder — R. G. Slauer
O. K. Hardacre — Walter Sturrock
John S. Walsh
and Regional Representatives

COORDINATING COMMITTEE FOR DEFENSE — To contact various Government Agencies concerned with National Security suggesting cooperation and participation in specific projects as an aid to solution of their problems. Recommending the placement of lighting study projects in present committees or the appointment of study project committees to the Society President and to expedite such study projects and guide accepted reports into proper Government channels.

A. F. Wakefield, Co-Chairman, The F. W. Wakefield Brass Co., Vermilion, Ohio.

G. D. Mills, Co-Chairman, 283 Osborne Ave., Britannia Heights, Ottawa, Ont.

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H. R. Blackwell — K. M. Reid
R. B. Brown, Jr. — John S. Walsh
O. P. Cleaver — M. N. Waterman

HISTORICAL — To assemble and make available for current reference and to prepare in suitable and durable form for posterity, such historical facts, printed memorabilia, photographs, voice records, museum specimens and allied items as may be judged worthy of composing a continuing digest of the record of the Society's history.

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Julius Daniels — C. A. B. Halvorson
Leo Delkart — J. L. Stair
G. H. Stickney

LIGHTING SERVICE — To stimulate and promote the discussion and practical application of lighting recommendations and to conduct a Lighting Service Forum in connection with the National Technical Conference.

L. E. Tayler, Chairman, The Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

William T. Clark — Paul H. Hildebrand

MEMBERSHIP — To develop plans and supervise the operation of the individual membership activity of the Society.

T. W. Lauer, Chairman, Rumsey Electric Co., 1007 Arch St., Philadelphia, Pa.

W. A. Stannard, Vice-Chairman, Consumers Power Co., 212 W. Michigan Ave., Jackson, Mich.

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E. M. Fahey — L. C. Twichell
E. H. Salter — J. S. Walsh
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NATIONAL TECHNICAL CONFERENCE — To be completely responsible, subject to the approval of Council, for the general coordination of all conference activities, for selecting and recommending time and place for review of the plans and budgets of the National Technical Conference Executive Committee and in cooperation with the Papers Committee for the satisfactory time allocation for the Technical Papers sessions according to Procedures and Policies as adopted by Council.

C. N. Laupp, Chairman, Wisconsin Electric Power Co., 231 W. Michigan St., Milwaukee, Wis.

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R. M. Fabel

Conference Executive Committee

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M. E. Keck — N. H. Vacha
T. D. Wakefield

PROCEDURES AND POLICIES — To study problems of Society procedure and policy referred to the Committee by Council, and to formulate recommendations to Council for the statement, revision, or clarification of these procedures and policies consistent with the Constitution and Bylaws of the Society.

G. W. Beals, Chairman, The Miller Co., Meriden, Conn.

C. C. Shotwell — L. C. Twichell
W. A. Stannard — J. S. Walsh
E. M. Strong — J. F. Whitehead, Jr.
F. C. Winkler

PUBLIC RELATIONS AND INFORMATION — To prepare and disseminate information about the activities, accomplishments, program, objectives and policies of the Society and about the place of illuminating engineering in modern society; to formulate and submit public relations policies and plans for the Society.

J. F. Whitehead, Jr., Chairman, Day-Brite Lighting Inc., 5411 Bulwer Ave., St. Louis, Mo.

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A. H. Clarke — R. M. Johannesen
B. C. Cooper — T. W. Lauer
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J. P. Sadler — E. J. Whitlow
Peter Sarafin — William Winglar
M. W. Zeeb

REGIONAL ACTIVITIES — To represent the respective Regions before the Council and to keep the Council informed regarding the affairs of the Regions. To stimulate Society activities, to encourage joint meetings of Sections and Chapters including Regional Conferences within the respective Regions and to promote the expansion of the Society.

M. N. Waterman, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

C. J. Berry — C. W. McCormick
G. B. Buck II — M. J. Myers, Jr.
J. R. Chambers — G. E. Park
D. M. Finch — B. E. Plowman
M. B. Hastings — A. C. Sangster

RESIDENCE LIGHTING FORUMS — To stimulate and assist the Residence Lighting Forums of the Society and to encourage the formation of additional Forums. To conduct a Residence Lighting Forum in connection with the National Technical Conference.

Mary B. Taepke, Chairman, The Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

Edith Buchholtz — Evelyn Herron
Mrs. Ralph L. Bush — Katharine T. Goodall
Mariquita Dygert — Jan Reynolds
Lillian Eddy — Frances E. Rosier
Eve Freyer — Kerr Sanders, Jr.
Virginia Skinner

SUSTAINING MEMBERSHIP — To develop plans and supervise the operation of the Sustaining Membership activity in the Society according to the Procedures and Policies adopted by Council.

C. C. Shotwell, Chairman, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

R. L. Biesele — R. A. Palmer
G. F. Dean — W. E. Potter
Fred Guth — T. C. Sargent
C. R. Long — H. T. Rankin
F. C. Winkler

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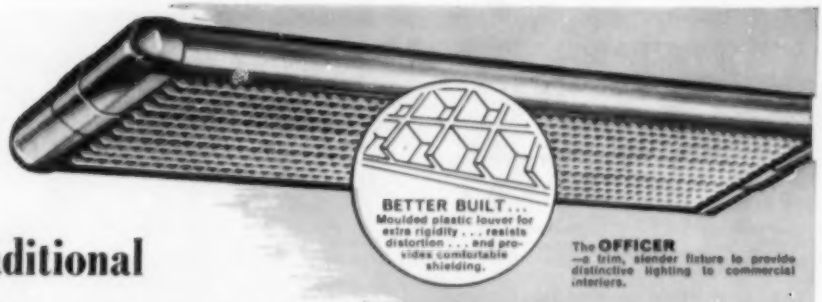
J. W. Young

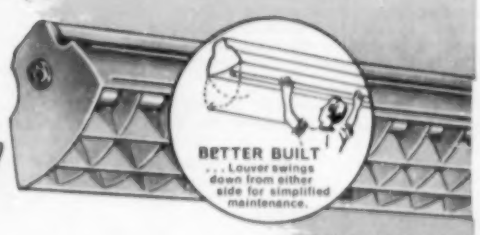
TRUSTEES, I.E.S. HEADQUARTERS RETIREMENT PENSION PLAN

E. M. Strong, Chairman, Cornell University, Ithaca, N. Y.
W. W. Booth — A. H. Manwaring
G. J. Taylor

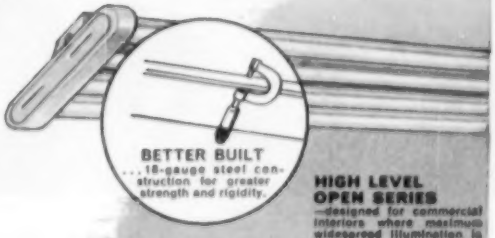
(Continued on page 24A)



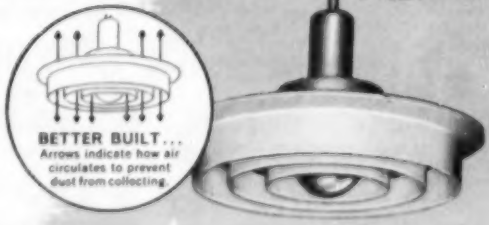
The **OFFICER**
—a trim, slender fixture to provide distinctive lighting to commercial interiors.



The **SCHOOLMASTER**
—an all-steel unit which provides upward light for comfort lighting, ideal for close seeing.



HIGH LEVEL OPEN SERIES
—designed for commercial interiors where maximum widespread illumination is desired, and low cost is a "must"!



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—meets rigid requirements of Boards of Education for economy combined with quality light.

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"Better Built Quality"

specify

Leader Line

Commercial Lighting Units

It is good business to insist on units with "Better Built" features like those illustrated here. That's because such features help cut operating costs, speed up and simplify maintenance, and insure reduced obsolescence and long-life dependability.

It is good business for the user, because such units give better service and save more money. It is good business for those who recommend and install lighting equipment, because the installation of such units results in greater satisfaction and increased good will.

Shown here are but a few Benjamin Leader Line units, each with just one of its "Better Built" features. Manufacturing "Better Built" lighting equipment is a tradition with Benjamin. That's why you can rely on getting Benjamin Quality in every Leader lighting unit.

For a complete showing of the Benjamin Leader Line, send for our FREE CATALOG.

TROFFERLITE with Holophane Controlens*—designed for locations where controlled quality lighting is desired.

*Copr., the Holophane Co.

BETTER BUILT
TO SERVE YOU BETTER

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Leader Line

Exclusive licensee of the Leader Line in Canada: Robertson Irwin Limited, Hamilton, Ontario

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Leader Division of Benjamin Electric Manufacturing Company, Dept. I, Des Plaines, Illinois . . . makers of famous Benjamin and Leader Line lighting equipment and sound signals for Industry, Institutions and Commerce.

B-627 BR

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C. M. Cutler	R. G. Slauer
R. F. Hartenstein	J. S. Walsh

I.E.S. - U. S. PUBLIC HEALTH SERVICE — To outline a method of making a survey of the visual factors of the working environment and the workers' vision and evaluating the findings in terms of visual comfort and effectiveness and eye health.

J. F. Parsons, Chairman, Niagara Mohawk Power Corp., 535 Washington St., Buffalo 3, N. Y.

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L. J. Cahill	Neal Jacobus
Mrs. Tula Brocard	A. L. Koven

R. P. Teele

TECHNICAL COMMITTEES

AVIATION — To study the application of light and lighting to the spaces and functions involved in the operation of aircraft.

D. C. Miller, Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

H. J. C. Pearson, Vice-Chairman, Civil Aeronautics Administration, Technical Development Division, Indianapolis, Ind.

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R. J. Stefany, Treasurer, Westinghouse Electric Corp., Bloomfield, N. J.

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I. F. Fagin	R. G. Slauer
W. C. Fisher	L. C. Vipond
J. F. Hoxie	Martin Warskow

A. B. Winters

CIVIL DEFENSE — To appraise and report on special lighting problems connected with emergency military operations that directly involve civilian defense and protection, such as equipment for bomb shelters, special street and vehicular lighting, mobile self-contained lighting facilities for use in bombed areas, emergency lighting devices and visual aids to movement in the event of power failure.

J. C. Forbes, Co-Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

J. W. Bateman, Co-Chairman, Canadian General Electric Co, Ltd., 165 Dufferin St., Toronto, Ont.

J. S. Walsh, Secretary, Pacific Gas & Electric Co., 245 Market St., San Francisco., Calif.

Subcommittee on Development of Technical Booklet

R. B. Brown, Jr., Chairman, Boston Edison Co., 39 Boylston St., Boston, Mass.

J. E. Dawson	W. P. Lowell, Jr.
R. M. Hoot	A. A. Pierce
Merle Keck	R. P. Teele
J. W. Lee	J. W. Young

COLOR — To study, evaluate and report on the effect of color in relation to the art and science of illumination.

R. C. Allison, Chairman, T. Eaton Co., 190 Yonge St., Toronto, Ont.

W. C. Granville, Vice-Chairman, Container Corp. of America, 38 S. Dearborn St., Chicago, Ill.

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Dean Farnsworth	W. D. Riddle
C. E. Foss	Francis Scofield
S. K. Guth	D. E. Spencer
R. M. Hanes	G. F. Wakefield

DAYLIGHTING — To study the problems involved in daylighting, develop recommended practices and report thereon.

R. A. Miller, Chairman, Pittsburgh Plate Glass Co., 420 Fort Duquesne Blvd., Pittsburgh, Pa.

H. B. Vincent, Vice-Chairman, Owens-Illinois Glass Co., 1700 N. Westwood Ave., Toledo, Ohio.

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G. N. Hingston	Andrew Vogel
H. F. Kingsbury	K. C. Welch
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Availability of Daylighting (Exterior)

R. F. Greene, Chairman, 100 W. 42nd St., New York, N. Y.

R. A. Boyd	J. W. Griffith

H. F. Kingsbury

Lower Ceiling Classrooms

H. F. Kingsbury, Chairman, Pittsburgh Corning Corp., Port Allegany, Pa.

C. J. Allen	R. V. Hall
J. W. Griffith	C. A. Winkelhake

Measurement and Reporting of Daylight

E. E. Vezey, Chairman, Texas Engineering Experiment Station, College Station, Texas.

J. W. Griffith	D. E. Spencer

DESIGN PRACTICE — To study published data on coefficients of utilization, room indexes, maintenance coefficients and other elements entering into calculations for lighting design; develop standard methods for use in Society publications and report thereon.

B. S. Benson, Jr., Chairman, Benjamin Electric Mfg. Co., Des Plaines, Ill.

G. W. Clark	J. A. Losh
Ward Harrison	J. J. Neidhart
Neal Jacobus	J. F. Parsons
J. Roy Jones	W. M. Potter
J. O. Kraehenbuehl	G. G. Rae
Norman Kridel	E. H. Salter

EDUCATION — To prepare educational and training programs on the fundamentals of illumination, lighting design problems and advance theories of light and lighting application. To prepare required text material and to further their adoption locally.

H. H. Magdsick, Chairman, 15724 Brewster Rd., Cleveland, Ohio.

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W. H. Billhartz	J. O. Kraehenbuehl
L. H. Brown	R. W. McKinley
R. I. Bull	R. C. Putnam
Robert Burnham	E. M. Strong
O. P. Cleaver	L. E. Tayler
A. A. Eastman	R. S. Wiseman
W. V. C. Foulks	I. A. Yost

Subcommittee on Survey of Employment Potential for Professionally Trained Illuminating Engineers

W. V. C. Foulks, Chairman, Curtis Lighting Inc., 6135 W. 65th St., Chicago 38, Ill.

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O. P. Cleaver	L. E. Tayler
R. W. McKinley	I. A. Yost

Subcommittee on Curriculum

L. H. Brown, Chairman, Stanford University, Stanford, Calif.

Abraham Abramowitz	R. C. Putnam
W. A. Hedrich	E. M. Strong
J. O. Kraehenbuehl	R. S. Wiseman

Subcommittee on Revision of "Experiments with Light"

A. A. Eastman, Chairman, General Electric Company, Nela Park, Cleveland, Ohio.

W. H. Billhartz	R. D. Burnham

FARM — To study the application of light and lighting of farm buildings, surrounding work areas and other rural locations and to report thereon.

O. C. Lange, Chairman, Pennsylvania Power & Light Co., 9th & Hamilton Sts., Allentown, Pa.

T. M. Barr	L. E. Innis
Edith Buchholtz	Arthur Kramer
J. P. Ditchman	Howard Long
O. D. Hunt	Joseph Schaenzer

A. J. VonBurg

I.E.S. - A.S.H.V.E. JOINT COMMITTEE — To study the relationship between lighting and various factors that enter into the thermal environment and report thereon.

Walter Sturrock, Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

R. W. McKinley	E. H. Salter

A.S.H.V.E. Cooling Load Subcommittee

John Everetts, Jr.	A. T. Jorn

J. N. Livermore

ILLUMINATION PERFORMANCE RECOMMENDATIONS — To prepare illumination performance recommendations for luminaires conforming to CIE classifications, excluding residential.

B. S. Benson, Jr., Chairman, Benjamin Electric Mfg. Co., Des Plaines, Ill.

R. D. Burnham	J. F. Parsons
G. W. Clark	E. H. Salter
Kurt Franck	R. P. Teele
W. H. Kahler	William Weibel

INDUSTRIAL — To initiate, follow up and coordinate lighting study projects in the industrial field, review the reports of the various subcommittees in this field and make recommendations to Council.

W. P. Lowell, Jr., Chairman, Sylvania Electric Products Inc., Ipswich, Mass.

A. A. Brainerd	C. C. Keller
J. R. Chambers	E. A. Linsday
W. H. Kahler	Howard Long

Central Station Properties

L. G. Parks, Chairman, Ebasco Services Inc., 2 Rector St., New York, N. Y.

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H. F. Carroll	Howard Long
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R. W. Corwin	C. B. Stephens
H. E. D'Andrade	D. W. Taylor

Clothing Industry

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L. Gauthier	B. A. Thomas
W. E. Hayes	L. C. Twichell

Carl Uthe

(*Continued on page* 27A)

Architect:
Roger C. Kirchhoff

Lighting Engineer:
Albert M. Koga
Hub Electric Co.

Electrical Contractor:
Russell Hainstock
Havey Electric Co.

Consulting Engineers:
Robert E. Hattis

Luminaires:
Corning Alba-Lite

A main lobby in the University of Wisconsin Memorial Library. Drop bowls of Corning Alba-Lite create interest in the ceiling, prevent any feeling of "weight." Luminaires are easy to maintain.

Alba-Lite equipped luminaires blend in perfectly with the architectural scheme, enriching the various colors through warm, soft, complementing light. Each luminaire has four 75-watt lamps. Illumination level is 45 foot-candles and can be increased simply by installing lamps of higher wattage.

Complex requirements determine choice of Alba-Lite in $5,000,000 University Library

How would *you* choose luminaires for key areas in one of the world's largest and most beautiful university libraries?

The architects and engineers set up a list of rigid lighting requirements for the University of Wisconsin Memorial Library. Against this list, they evaluated all possible choices to select the one that would best meet their standards.

When it came to luminaires for lobbies and corridors, the choice was large luminous elements with 24" square bowls of Corning Alba-Lite.

Luminaires equipped with Alba-Lite possess the qualities of character and beauty required in a building so richly conceived. They are distinctive without being conspicuous—another key point on the architect's list. And they highlight the beauty of architectural design, besides having a look of "belonging."

Pleased with results

Alba-Lite filled the requirement of variation in light output without obvious difference in brightness. And, the luminaires also fit into the long-term picture of low maintenance cost. A wipe with a damp cloth keeps Alba-Lite looking bright and new. And there's never any discoloration or fading with age.

How would you summarize final results? The completion report said simply, "The architect was immensely pleased with results."

And that about sums up the opinion of everyone who is concerned with Alba-Lite installations. We'll be happy to send you complete information on beautiful, practical and versatile lightingware, if you'll just return the coupon.

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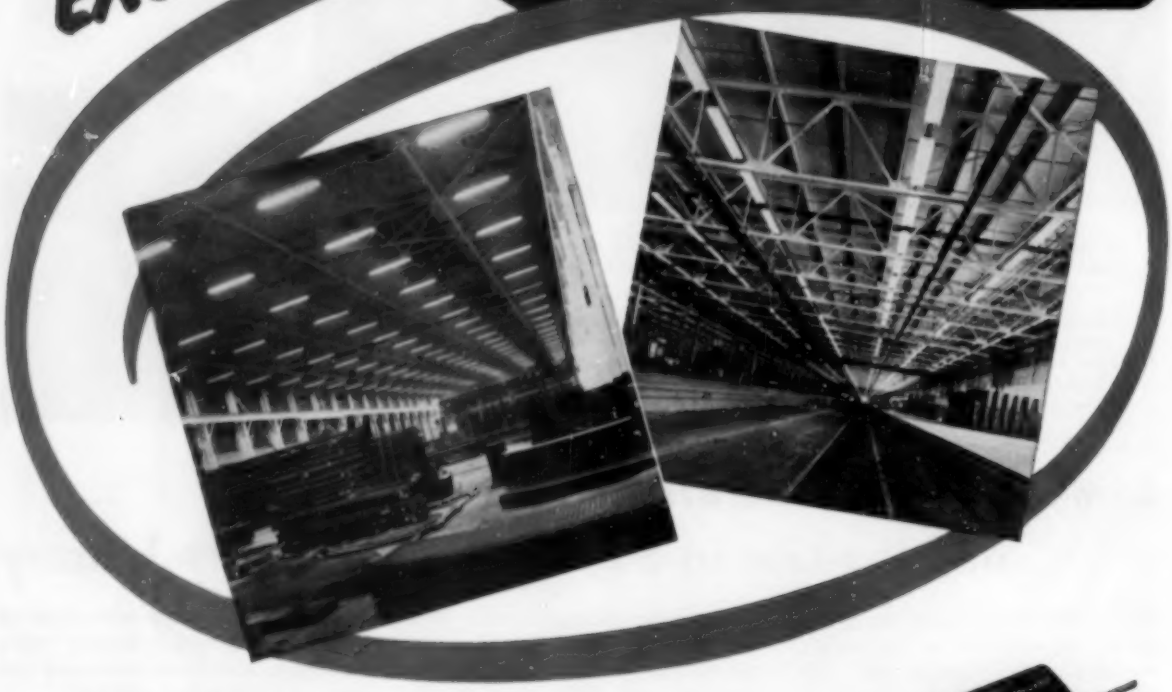

ADVANCE FLUORESCENT LAMP BALLASTS USED IN TWO FORD PLANTS

Views of the two new Ford Plants, one in the Engineering and Research Center, Dearborn, Mich. (upper picture) and the new aircraft wing plant at Claycomo, Missouri, show the use of fluorescent lighting installations. Both installations use ADVANCE "Certified" fluorescent lamp ballasts, specified by the fixture manufacturers responsible for the lighting efficiency. Why not take a tip from successful contractors and use dependable ADVANCE Ballasts too.

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(*Continued from page 24A*)

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W. M. Caldwell — J. A. Lansing
F. E. Mueller

Graphic Arts — Printing Industry

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William Harrison — Robert E. Rossell
Percy Holmes — Warren B. Reese
J. Wallace Scott

Subcommittee on Color Appraisal

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Norman Macbeth, Vice-Chairman, Macbeth Corp., Newburgh, N. Y.

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P. R. Holmes — Phillip Simone
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A. A. Sobolik, Jr., Chairman, Public Service Co. of Northern Illinois, 1701 South First Ave., Maywood, Ill.

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T. C. Wier

Sawmills

James Barnes, Chairman, Pacific Gas & Electric Co., North Bay Division, P.O. Box 540, San Rafael, Calif.

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Emanuel Fritz — Norman Schiewe
Jerry Howard — P. S. Schmidt
John Keyes — K. B. Stoddard

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Floyd W. Sell ,Chairman, Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

J. M. Marlin — T. H. Roughley
Donald Thiesen

Textile Industry

(Joint Committee with A.S.M.E.)

Carl M. Holden, Chairman, Champion Lamp Works, 600 Broad St., Lynn, Mass.

INSTITUTIONAL — To initiate, follow up and coordinate lighting study projects in the field of public buildings and private institutions, review the report of the various study subcommittees in this field and make recommendations to Council.

James H. McCulloch, Chairman, 421 W. Swisher St., Danville, Ill.

Joel Rubin — George Smedberg
C. I. Sayles — W. H. Smith
R. M. Smart — Carl Zersen

Auditoriums and Churches

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Kitchens

Carl Zersen, Chairman, Chicago Lighting Institute, 37 So. Wabash Ave., Chicago, Ill.

Theaters

Joel Rubin, Chairman, Kliegl Bros., Inc., 321 W. 50th St., New York, N. Y.

Jules C. Berinstein — G. T. Howard
Alfred Boylen — H. D. Sellman
T. W. Butler — George Smedberg
Theodore Fuchs — Rollo G. Williams

LIGHT CONTROL AND EQUIPMENT DESIGN — Collect and correlate the knowledge and data on means and methods of controlling, directing, reflecting, transmitting and diffusing light and on the principles and practices of equipment design.

D. L. Williams, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

F. M. Neal, Vice-Chairman, Corning Glass Works, Corning, N. Y.

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B. S. Benson, Jr. — C. N. Sprankle
R. D. Bradley — M. Trostle
G. C. Moore — William Weibel
F. C. Winkler

Joint Subcommittee—I.E.S., S.P.I. and N.E.M.A.

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W. C. Goggins, Vice-Chairman, The Dow Chemical Co., Midland, Mich.

R. D. Bradley — W. P. Lowell, Jr.
J. S. Capps — Carl O. Massopust
A. J. Dragonette — F. W. Ogden
W. F. Fitzgerald — C. Rackel
G. Gilleard — E. H. Salter
E. A. Haddad — E. Szantay
Carl Holch — G. P. Wakefield
H. A. Williams

General Requirements

George Gilleard, Chairman, Curtis Lighting Inc., 6135 W. 65th St., Chicago, Ill.

M. H. Bigelow — Jack Pecktal
R. D. Bradley — E. H. Salter
N. E. Brown — Elmer Szantay
E. A. Haddad — George Wakefield
F. C. Winkler

Maintenance

W. M. Bagley — John Murphy
A. J. Dragonette — Henry Peterson
W. C. Goggin — H. A. Williams
E. Y. Wolford

Properties and Measurements

E. A. Haddad, Chairman, Monsanto Chemical Co., Springfield, Mass.

G. R. Baumgartner — Henry Peterson
A. J. Dragonette — Jules Pinsky
W. J. Fitzgerald — C. Rackley
R. T. Holtz — E. H. Salter
E. E. Kotkin — H. A. Williams
W. P. Lowell, Jr. — P. C. Woodland

LIGHT SOURCES — To correlate and report available information as to the physics of light and light production and the characteristics of current light sources.

H. F. Davidson, Chairman, Hydro-Electric Power Commission of Ontario, 620 University Ave., Toronto, Ont.

E. H. Salter, Vice-Chairman, Electrical Testing Laboratories, Inc., 2 East End Ave. & 79th St., New York, N. Y.

Charles Amick — B. F. Greene
Herbert Anderson — E. F. Lowry
L. E. Barbrow — W. W. Lozier
George Freeman — E. H. Raddin

Color Rendition

Dorothy Nickerson, Chairman, 2039 New Hampshire Ave. N. W., Washington 9, D. C.

C. N. Clark — G. R. Stillwell
C. W. Jerome — C. E. Swanson
D. B. Judd — Luke Thorington
Norman Macbeth — Arthur Weeks

MAINTENANCE — To study the elements contributing to maintenance factors; set up the framework of typical field studies to determine factors; and to stimulate the prosecution of such studies by appropriate agencies.

James W. Tuttle, Secretary, General Electric Co., Nela Park, Cleveland, Ohio.

R. D. Bradley — C. M. Holden
A. A. Brainerd — M. E. Keck
R. D. Burnham — Howard Long
Francis Clark — Bert C. Pretzer
H. R. Davies — R. P. Teele
L. M. Endres — I. E. Zastrow

MOTOR VEHICLE LIGHTING (EXTERIOR) — To study the problems of illuminating the night operations of motor vehicles and to make suitable recommendations for promoting maximum safety and convenience including accessory illuminated signal and traffic aids.

R. P. Teele, Chairman, National Bureau of Standards, Washington, D. C.

L. L. Beltz — William Groth
W. E. Carpenter — Burton Marsh
L. W. Chubb — Charles Marsh
Elliott Daniels — G. L. McCain
H. F. Davidson — V. J. Roper
Neil Dormstadter — A. Rugo
R. N. Falge — W. E. Schwanhausser
D. M. Finch — Edmund R. Ricker

NOMENCLATURE — To define the terms and standards of illumination, and endeavor to obtain uniformity in nomenclature.

Priscilla Presbrey, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

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E. Q. Adams — H. P. Gage
L. E. Barbrow — S. K. Guth
Robert Bromberg — W. F. Little
C. L. Cottrell — W. W. Menke
Harris Reinhardt

OFFICE — To study the lighting requirements of office lighting tasks, develop suitable lighting recommendations and report thereon.

John J. Neidhart, Chairman Westinghouse Electric Corp., 1216 W. 58th St., Cleveland, Ohio.

G. F. Dean, Vice-Chairman, Toronto Hydro-Electric System, 14 Carlton St., Toronto, Ont.

A. S. Almryde — R. L. Oetting
C. T. Bakeman — G. G. Rae
David Bluford — T. H. Shepherd
L. M. Endres — G. J. Taylor
W. E. Folsom — Roger T. Waite
C. W. Macy — G. P. Wakefield
R. W. McKinley — R. R. Wylie
R. L. Zahour

PROGRESS — To keep in touch with developments in the art of lighting throughout the world and prepare a yearly review of achievements in the art of illuminating engineering for inclusion in ILLUMINATING ENGINEERING.

E. W. Beggs, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

C. L. Amick, Vice-Chairman, General Electric Company, Cleveland, Ohio.

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O. P. Cleaver	H. F. Kingsbury
Kurt Franck	J. H. McCulloch
John Gornet	J. A. Meacham
B. F. Greene	T. C. Sargent
Arthur R. Jaeger	R. P. Teele

H. A. Williams

PROTECTIVE — To prepare standards for protective lighting of plants, yards, boundary fences, adjoining highways, railroad sidings, and waterway approaches for the purpose of reducing fire and theft risks, and making policing more effective.

J. W. Lee, Chairman, Philadelphia Electrical & Mfg. Co., 1236 N. 31st St., Philadelphia, Pa.

Quentin Dobras	Van Edward Marker
M. C. Harsh	D. W. Rowten
H. E. Mahan	G. G. Rae

PUBLIC CONVEYANCES (INTERIOR) — To study the application of light to all public areas in conveyances used for passenger transportation, including particularly trains, buses, ships, street railways and subways, and report thereon.

C. E. Egeler, Chairman, 3014 Berkshire Rd., Cleveland, Ohio.

A. L. Arenberg	F. T. Snider
E. Boghosian	J. B. Spillane
J. C. de la Rosa	J. L. Swarner
J. B. Feder	R. L. Sweeney
E. B. Hallman	R. M. Timmins
T. S. Madonia	A. Vandevelde
M. A. Mortensen	W. C. Wheeler

Interior Lighting — Land Transportation

J. L. Swarner, Chairman, Pullman Standard Car Mfg. Co., 10909 Cottage Grove Ave., Chicago, Ill.

A. L. Arenburg	C. B. Mackay
J. S. Bauer	T. S. Madonia
R. H. Bertsche	M. A. Mortensen
W. N. Bodkin	W. R. Preece, Jr.
J. C. de la Rosa	G. L. Sealey
E. B. Hallman	F. T. Snider
J. L. Heins	W. C. Wheeler

A. C. Zagotta

Interior Lighting — Marine Transportation

R. Timmins, Chairman, Gibbs and Cox., Inc., 21 West St., New York, N. Y.

W. M. Adrian	R. K. Johnson
E. Boghosian	T. S. Madonia
J. B. Feder	R. L. Sweeney
E. A. Geary	A. Vandevelde

Mainline Coach Lighting

E. B. Hallman, Chairman, Electric Service Mfg. Co., 17th & Cambria Sts., Philadelphia, Pa.

Wm. Bodkin	T. S. Madonia
C. B. MacKay	W. R. Preece

F. T. Snider

Suburban & Short Haul Coach Lighting

J. L. Swarner, Chairman, Pullman Standard Car Mfg. Co., 10909 Cottage Grove Ave., Chicago, Ill.

A. L. Arenberg	M. A. Mortensen
J. C. de la Rosa	W. C. Wheeler

A. C. Zagotta

Joint AAR-IES for Interior Lighting of Railroad Rolling Stock

J. L. Swarner, Chairman, Pullman Standard Car Mfg. Co., 10909 Cottage Grove Ave., Chicago, Ill.

A. L. Arenberg	W. R. Preece, Jr.
E. B. Hallman	G. L. Sealey
T. S. Madonia	F. T. Snider
M. A. Mortensen	A. C. Zagotta

RESEARCH PLANNING—To survey and report on all significant research dealing directly or indirectly with the application of light and lighting and its effect upon the performance and comfort of human beings not conducted by the I.E.S. Research Fund, to survey the whole field of lighting; to determine and report on subjects which require scientific verification through research, and to coordinate various types of research affecting lighting which are now being conducted by various agencies.

Willard Allphin, Chairman, Sylvania Electric Products Inc., Salem, Mass.

S. K. Guth	R. C. Putnam
H. L. Logan	Domina E. Spencer

RESIDENCE — To study and report on the application of light and lighting in residences; to develop performance recommendations for residence luminaires and to prepare necessary educational aids.

Frank Marriett, Chairman, Moe Light Inc., 700 Oak St., Fort Atkinson, Wisconsin.

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Mary E. Dodds	Priscilla Presbrey
Myrtle Fahsbender	Jan Reynolds
E. W. Halteman	Mary B. Tsapko
C. C. Keller	Morris Thau
Kaye Leighton	Norman Vacha

Performance of Portable Lamps

Mary Tsapko, Chairman, Detroit Edison Co., 2000 Second Ave., Detroit,, Mich.

Kaye Leighton	Priscilla Presbrey

Jan Reynolds

SCHOOL — To study the application of light and lighting to the spaces and processes involved in educational institutions and to report thereon.

J. M. Charlton, Chairman, Board of Education, 155 College St., Toronto, Ont.

C. J. Allen, Secretary, General Electric Co., Nela Park, Cleveland, Ohio.

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R. L. Biesele, Jr.	J. L. Kilpatrick
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L. H. Brown	H. L. Logan
Brooks Chassaing	J. D. MacConnell
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H. F. Davidson	J. F. Parsons
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Chalkboards

H. F. Davidson, Chairman, Hydro-Electric Power Commission of Ontario, 620 University Ave., Toronto, Ont.

Electrical Lighting Design

J. F. Parsons, Chairman, Niagara-Mohawk Power Corp., 535 Washington St., Buffalo, N. Y.

Student Vision and Scholarship

A. A. Eastman, Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

Visual Problems

Paul Seagers, Chairman, School of Education, Indiana University, Bloomington, Ind.

SEARCHLIGHT — To study the design and application of searchlights and to report thereon.

T. H. Projector, Chairman, National Bureau of Standards, Washington, D. C.

H. C. Smith, Secretary, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland, Ohio.

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R. S. Wiseman

SIGNAL LIGHTING, ELEMENTS OF — To compile a compendium of current information on all phases of signal lighting.

F. C. Breckenridge, Chairman, National Bureau of Standards, Washington, D. C.

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SPORTS AND RECREATIONAL AREA LIGHTING — To develop current recommended practices for lighting sports and recreational areas; study techniques of application including effects on player performance and spectator visibility and report thereon.

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STANDARDS OF QUALITY AND QUANTITY FOR INTERIOR ILLUMINATION — To prepare standards for illumination levels, brightness limits, brightness ratios for interiors, including specific visual tasks, as well as the general surroundings.

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STORE LIGHTING — To study the application of light and lighting to the spaces and processes involved in the selling of goods and to report thereon.

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STREET AND HIGHWAY LIGHTING — To establish the scientific principles underlying street and highway lighting; to collect data on the results of the application of such principles to actual practice; to prepare such reports thereon as will assist technicians and benefit the public.

C. H. Rex, Chairman, General Electric Co., 920 Western Ave., West Lynn, Mass.

G. K. Glass, Vice-Chairman, Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

INSTALLATION: Boyle County Court House, Danville, Kentucky.
AREA: County Court Room — Hon. Judge Cheek, County Judge.
ARCHITECTS & ENGINEERS: Nevin & Morgan, Louisville, Kentucky.
ELECTRICAL CONTRACTOR: Simpson Electric Co., Danville, Kentucky.
CEILING HEIGHT: 16 Feet, Approximately.
CEILING: Flat White.
WALLS: Light Green.
FLOOR: Brown Cork.
FIXTURES: Litecontrol No. 5828 2-lamp recessed louvered troffers and No. 5838 3-lamp recessed louvered troffers, using T1296 slimline lamps.
SPACING: 8'-6" on centers.
INTENSITY: Approximately 37 footcandles average in service.

LITECONTROL'S

CASE OF THE MISSING SHADOWS

Examine this courtroom carefully. Note the even illumination . . . the ease of seeing — designed to keep keen eyes and wits alert through tedious hours of legal battle.

Now, count the shadows! That's right. Not even one. Light but not bright, every point in this room offers maximum visibility — without harsh contrasts or tiring glare.

Secret here is standard LITECONTROL fixtures No. 5828 and No. 5838, slightly modified to arrange in rectangles. Better to look at, better to look with, these beautiful fixtures also reduce maintenance to a minimum.

For light, looks, and low cost on your next lighting installation — make yours standard fixtures by LITECONTROL.

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LITECONTROL CORPORATION, 36 Pleasant Street, Watertown 72, Massachusetts

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(Continued from page 28A)

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TECHNICAL COMMITTEE FORUM—To coordinate procedures of our technical committees and to sponsor a lighting application symposium at the National Technical Conference.

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D. W. Frick	S. C. Peck
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A. Jacobovitz	C. H. Singer

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Lighting Practices

(Camera characteristics, video control, lighting and instrumentation)

Reid Davis, Chairman, National Broadcasting Co., 30 Rockefeller Plaza, New York, N. Y.

S. Bonsignor — K. Palius

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Light Sources Required for Color Television

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Lighting Equipment for Color Television

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Guide for Brightness Measurements

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Guide for Electrical and Photometric Measurement of Mercury Vapor Lamps

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Guide for Photometry of Searchlights

A. E. Krawcek, Chairman, Crouse-Hinds Co., Syracuse, N. Y.

Practical Guide to Photometry

O. Phelps Meaker, Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

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(Continued on page 33A)

NEW!

Labor costs cut more than 50%

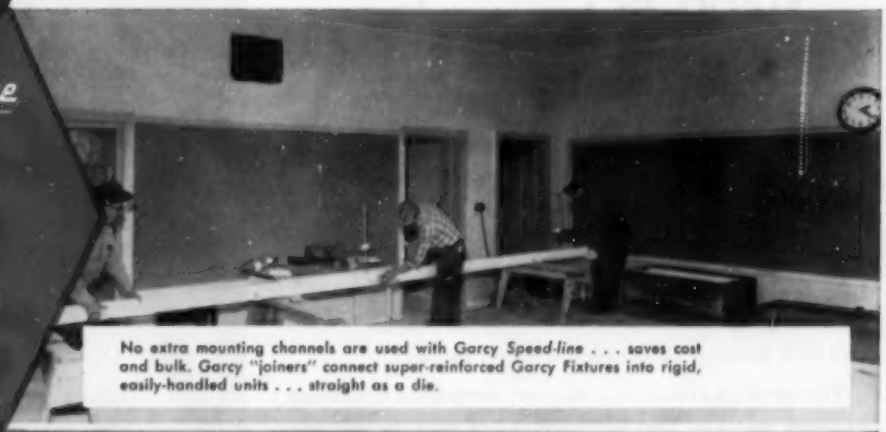
ON CONTINUOUS RUNS OF GARCY LIGHTING INSTALLED

with new *Speed-line* system

PATENT PENDING

WITH *Speed-line* FIXTURES ARE PRE-ASSEMBLED AND PRE-WIRED AT FLOOR LEVEL

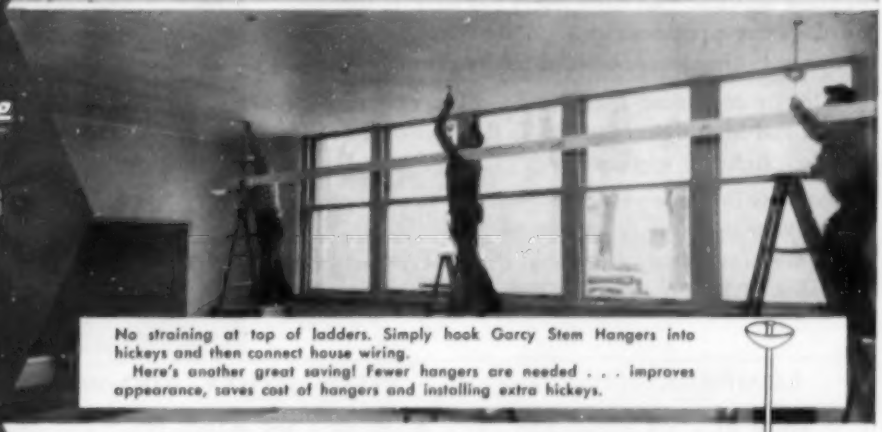
no separate external mounting channel needed



No extra mounting channels are used with Garcy *Speed-line* . . . saves cost and bulk. Garcy "joiners" connect super-reinforced Garcy Fixtures into rigid, easily-handled units . . . straight as a die.

WITH *Speed-line* ENTIRE RUN IS RAISED TO CEILING AS A SINGLE UNIT

. . . and uses fewer stem hangers



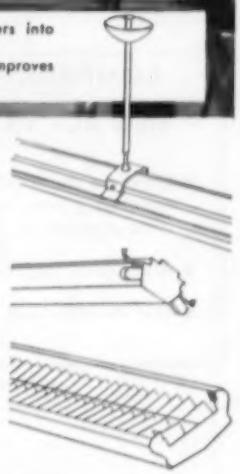
No straining at top of ladders. Simply hook Garcy Stem Hangers into hickeys and then connect house wiring.

Here's another great saving! Fewer hangers are needed . . . improves appearance, saves cost of hangers and installing extra hickeys.

WITH *Speed-line* YOU CAN DELIVER PREMIUM LIGHTING AT THE COST OF STANDARD FIXTURES

What a boon to contractors! The savings in labor cost enable you to quote a lower total price . . . and still furnish the highest quality commercial fixture made, the Garcy VISUALIER. *Speed-line* installation techniques were specially developed to take full advantage of the Garcy VISUALIER'S unique design features. Separate, lightweight wireways are easiest to handle. The separate, one-piece shielding bodies may be left in cartons, safe from dust and damage, until the job is ready to lamp and light.

Be the first in your area to offer this contract-winning advance. For budget jobs *Speed-line* is also available with Garcy's Gar-See-Lite fixtures.



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GARCY *Quality by Design*

GARDEN CITY PLATING & MFG. CO., 1760 N. Ashland Ave., Chicago 22, Ill.
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. . . another advance in mercury lighting from G. E.

Now 54% more light from G-E 400-watt mercury lamp

New General Electric H400-RC1 gives top color balance, too

In another mercury lighting first, General Electric has raised the light output of the H400-RC1 mercury lamp from 12,300 to 19,000 lumens! This 54% increase in efficiency results from using a special fluorescent phosphor as a reflector as well as to improve color balance. Its color characteristics are best of any mercury lamp for general lighting. Color rendition approximates a mixture of ⅓ filament light and ⅔ mercury light.

The new G-E H400-RC1 mercury lamp has a life rating of 6000 hours at 5 or more hours per start. It operates on the same equipment as all other 400-watt mercury lamps and is interchangeable in most reflectors.

With its controlled beam, good color, easy maintenance, and high light output, it is first choice for most mercury lighting applications.

For more information on how this new mercury lamp can fit your operation, call your G-E Lamp supplier, or write General Electric Company, Lamp Division, Dept. 166-IE-4, Nela Park, Cleveland 12, Ohio.

COMPARE NEW G-E RC1 WITH OTHER 400-WATT MERCURY TYPES

NEW RC1 VS H400-E1

- Light on the work equal or greater in most equipment
- Adds color balance
- Less maintenance

NEW RC1 VS H400-J1

- Delivers 10-20% more light on the work in most equipment
- Has somewhat better color balance
- Lower cost of light

NEW RC1 VS H400-A1

- 35% more light on the work in most equipment
- Has good color balance
- Lower cost of light

Progress Is Our Most Important Product

GENERAL ELECTRIC

(*Continued from page 30A*)

Photoelectric Portable Photometers — Revision of 1937 Report
G. A. Horton, Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland, Ohio.

Photometric Testing of Fluorescent Street Lighting Luminaires
J. S. Franklin, Chairman, General Electric Co., 920 Western Ave., West Lynn, Mass.
J. E. Bock G. A. Horton
T. H. Leister

Unified Test Report Form — Revision of
Elden H. Witte, Chairman, Benjamin Electric Mfg. Co., Des Plaines, Ill.
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Building Exits Code, A9
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American Standard Practice for Industrial Lighting, A11
(to be appointed)

American Standard Practice for School Lighting, A23
John Chorlton

Building Code Requirements for Light and Ventilation, A53
B. F. Greene

National Electrical Code, C1
G. E. Shoemaker, Panel 2, 3 and 10

Definitions of Electrical Terms, C42
Harris Reinhardt

Dimensional and Operational Standardization of Electric Lamps and Auxiliaries for Gaseous Discharge Lamps, C78
Thomas S. Kelly

Inspection Requirements for Motor Vehicles, D7.1
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Preferred Numbers, Z17
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Standardization of Optics, Z58
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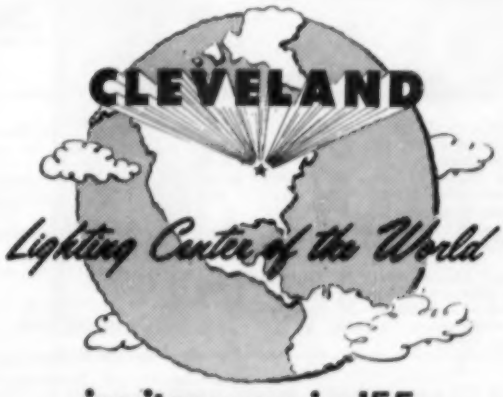

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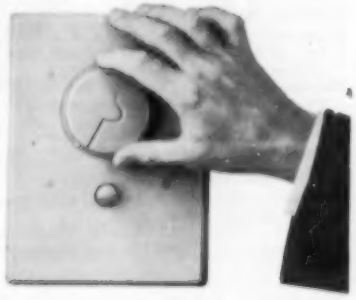

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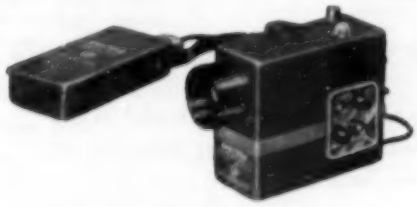

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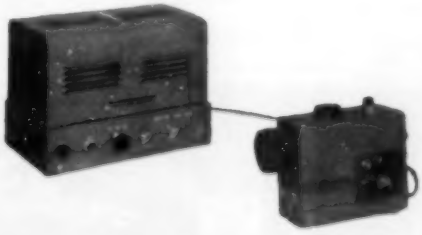

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Lexington, Va.—Col. J. S. Jamison, Jr., Virginia Military Institute.
New Castle, Pa.—R. L. James, Pennsylvania Power Co.
Newport News, Va. — Clarence P. Andrew, Noland Co.
Pottsville, Pa. — C. B. Staudt, Pennsylvania Power & Light Co.
Reading, Pa.—Frank E. Heins, Metropolitan Edison Co.
Richmond, Va. — George E. Schraudt, Jr., 812 St. Christopher Rd.
Salisbury, Md. — J. Russell Hopkins, Box 984.
Shenandoah, Pa.—Harry T. Weidman, Pennsylvania Power & Light Co.
Stroudsburg, Pa.—B. I. Fansler, Line Material Co.
Sunbury, Pa. — William H. Helm, Pennsylvania Power & Light Co.
Towanda, Pa.—C. T. Troy, Northern Pennsylvania Power Co.
Trenton, N. J.—Arthur L. Talbot, Public Service Electric & Gas Co.
Trucksville, Pa. — Edward T. Reilly, 118 Meadowcrest.
Williamsport, Pa.—Gleason E. Solley, Pennsylvania Power & Light Co.
Wilmington, Del.—Edward F. Lafond, Delaware Power & Light Co.
York, Pa.—Laurence O. Buckner, Metropolitan Edison Co.

Great Lakes Region

Akron, Ohio — L. O. Banahan, Ohio Edison Co.
Alliance, Ohio—J. C. Roberts, Ohio Edison Co.
Ann Arbor, Mich. — James L. Culp, Detroit Edison Co.
Auburn, N. Y. — P. J. Carpenter, 6 Elizabeth St.
Binghamton, N. Y.—Earl C. Edwards, N. Y. State Electric & Gas Co.
Canton, Ohio—C. L. Bullock, Ohio Power Co.
Corning, N. Y.—W. H. Dorman, R. D. 1.
Dayton, Ohio—R. J. Schulte, General Electric Co.
Elmira, N. Y.—F. H. Reese, LeValley, McLeod, Kincaid Co.
Elyria, Ohio—George C. Rubenson, Ohio Public Service Co.
Findley, Ohio—B. E. Spangler, Spangler Electric Co.
Flint, Mich.—George D. Hannah, Consumers Power Co.
Fostoria, Ohio—R. T. Woodruff, Ohio Power Co.
Grand Rapids, Mich.—Harold P. Earley, Consumers Power Co.
Huntington, W. Va. — William M. Langstaff, Appalachian Electric Power Co.
Ithaca, N. Y. — Prof. C. L. Cottrell, Cornell University.
Jackson, Mich. — Robert S. Schoff, General Electric Co.
Lexington, Ky.—Robert W. Wilson, Kentucky Utilities Co.
Lima, Ohio—J. W. Jones, Ohio Power Co.
Louisville, Ky.—Edward J. Good, Louisville Gas & Electric Co.
Mansfield, Ohio—Orio L. Smith, Ohio Public Service Co.
Marion, Ohio—Leroy Clauer, Ohio Edison Co.
Massillon, Ohio—Andrew Hrivnak, Ohio Edison Co.
Monroe, Mich.—Keith E. Hunt, Detroit Edison Co.
Newark, Ohio — Kurt Franck, Holophane Co., Inc.
Pontiac, Mich.—T. F. Donaldson, Consumers Power Co.
Port Huron, Mich.—James Abernethy, Detroit Edison Co.
Saginaw, Mich.—Earl R. Domoney, Consumers Power Co.
Sandusky, Ohio — C. H. Smith, Ohio Public Service Co.
Syracuse, N. Y.—D. G. Geyer, 506 Glenwood Ave.
Toledo, Ohio—A. H. Stevenson, Box 497 M.O.
Utica, N. Y. — John C. Bannigan, Niagara Mohawk Power Corp.
Warren, Ohio—Walter C. Schultz, Ohio Edison Co.
Youngstown, Ohio—Robert Zimmerman, Ohio Edison Co.

Inter-Mountain Region

Cheyenne, Wyo. — W. B. Petch, Cheyenne Light, Fuel and Power Co.
Prescott, Ariz.—George Hill, Northern Arizona Light & Power Co.
Roswell, N. M. — William W. Dayton, Southwestern Public Service Co.
Tucson, Ariz. — W. H. Hughes, Hughes Aircraft Co.

Midwestern Region

Ames, Iowa — Warren B. Boast, Iowa State College.
Belleville, Ill.—Ray Funk, Illinois Power Co.
Bismarck, N. D. — Marvin R. Hooge, Montana Dakota Utilities Co.
Cedar Rapids, Iowa — Ray Goodwater, The Van Meter Co.
Centerville, Iowa—Paul Anderson, Iowa Southern Utilities Co.
Clinton, Iowa—Leonard D. Rafferty, Interstate Power Co.
Davenport, Iowa — Fenn C. Horton, General Electric Co.
Decatur, Ill.—Gordon Bonvallet, R. R. #7.
Des Moines, Iowa — James H. Hull, Day-Brite Lighting Inc.
Dubuque, Iowa — Richard Holcomb, Interstate Power Co.
Eau Claire, Wis.—John June, Northern States Power Co.
Fairmont, Minn. — B. L. Whitney, Water & Light Commission.
Faribault, Minn. — A .B. Hallaway, Northern States Power Co.
Green Bay, Wis. — A. G. Blitz, Wisconsin Public Service Corp.
Iowa City, Iowa — John R. Wilson, Iowa-Illinois Gas & Electric Co.
Jefferson City, Mo. — Donald D. Jones, R. R. #3, Bluff St.
LaCrosse, Wis. — C. L. Seaquist, Northern States Power Co.
Madison, Wis.—George R. Byington, Wisconsin Power & Light Co.
Mankato, Minn. — L. A. Gauthier, Northern States Power Co.
Mason City, Iowa — Willard Hunter, 1011 N. Jefferson Ave.
Mt. Vernon, Ill. — Harry L. Sharer, Mt. Vernon Electric Supply.
Notre Dame, Ind.—Prof. L. F. Stauder, University of Notre Dame.
Ottumwa, Iowa — Paul Rohner, Crescent Electric Supply Co.
Rochester, Minn.—Donald H. Nietz, 30 Seventh Ave. N. E.
Rockford, Ill. — O. W. Pollard, Central Illinois Electric & Gas Co.
St. Cloud, Minn.—W. B. Hall, Northern States Power Co.
Ste. Genevieve, Mo. — H. A. Giesler, Citizens Electric Corp.

E. St. Louis, Ill.—Horace Brown, Sachs Electric Co.
Sioux Falls, S. D.—James H. Gibbs, Tri-State Electric Co.
South Bend, Ind. — Prof. L. S. Stauder, University of Notre Dame.
Springfield, Ill.—J. Walter Marquardt, 322½ E. Adams St.
Springfield, Mo. — Chester G. Wells, Harry Cooper Supply Co.
Streator, Ill.—Hubert W. Knight, Public Service Co. of Northern Illinois.
Urbana, Ill. — Prof. Harry W. Horn, University of Illinois.
Waterloo, Iowa — J. C. Gehan, 711 Lime St.
Wausau, Wis.—G. M. Kammerer, Wisconsin Public Service Corp.

Northeastern Region

Augusta, Me. — Raymond B. MacFarland, 9 Green St.
Bangor, Me.—Wilbur D. Chadeayne, Bangor-Hydro Electric Co.
Bridgeport, Conn. — Joseph Barney, General Electric Supply Co.
Bridgeport, Conn.—H. L. Steinhardt, 2254 Park Ave.
Dover, N. J. — J. W. Haynes, New Jersey Power & Light Co.
Essex, Conn. — Ralph Marrone, Connecticut Light & Power Co.
Glen Falls, N. Y. — Joseph P. Quinn, Niagara Mohawk Power Corp.
Gloversville, N. Y.—Charles E. Shell, B. E. Shell Co.
Hartford, Conn.—J. F. Dougherty, Hartford Electric Light Co.
Hartford, Conn.—R. M. Harris, Westinghouse Mfg. Co.
Hartford, Conn.—J. Schonbrun, Brown Light & Supply Co.
Lawrence, Mass.—Henry R. Loeschner, Lawrence Gas & Electric Co.
Little Compton, R. I. — Paul Manchester.
Meriden, Conn. — A. B. Smith, Connecticut Light & Power Co.
Meriden, Conn. — E. Gonya, Jr., The Miller Co.
Mineola, N. Y.—J. F. Dickerhoff, Long Island Lighting Co.
Morristown, N. J.—G. L. Estler, Jersey Central Power & Light Co.
New Bedford, Mass.—Robert R. Duncan, Jr., New Bedford Gas & Edison Light Co.
New Britain, Conn. — A. Heartstein, Ruby Philite Co.
New Brunswick, N. J.—M. S. Ewing, Public Service Electric & Gas Co.
New Haven, Conn.—Peter Zona, 110 Franklin St.
Newark, N. J.—J. F. MacDougall, General Electric Co.
New York, N. Y.—Prof. Abraham Abramowitz, 955 Walton Ave.
North Adams, Mass.—Bartholomew D. Barry, Jr., Northern Berkshire Electric Co.
North Bergen, N. J. — H. A. Anderson, Duro Test Corp.
Norwalk, Conn. — H. B. Adams, River Rd.
Portland, Me. — P. E. Weatherbee, Box 1801.
Poughkeepsie, N. Y. — T. M. Barr, Central Hudson Gas & Elec. Corp.
Schenectady, N. Y.—Ellsworth S. Coe, 1220 Lexington Ave.
Springfield, Mass.—Jack O. Callander, Western Massachusetts Electric Co.
Troy, N. Y.—Harry E. Rodman, Rensselaer Polytechnic Institute.
West Madison, Conn. — O. B. Weeks, Overshore Rd.
Willimantic, Conn.—M. R. Sugrue, Connecticut Light & Power Co.
Worcester, Mass. — W. S. Mowry, Worcester County Electric Co.

Pacific Northwest Region

Albany, Ore. — Dr. Herbert P. Johnson, 240 W. First St.
Beaverton, Ore. — Don L. Shattuck, Portland General Electric Co.
Bellingham, Wash. — Phil T. Rosser, Puget Sound Power & Light Co.
Bremerton, Wash.—Eldon A. Matlock, Puget Sound Power & Light Co.
Butte, Mont. — Oram J. Horrom, Montana Power Co.
Coeur d'Alene, Idaho—Alec Godfrey, Washington Water Power Co.
Corvallis, Ore.—Prof. D. W. Shirley, Oregon State College.
Davenport, Wash.—Tony Aichlmayr, Washington Water Power Co.
Ephrata, Wash.—Don Hansen, P. O. Box 965.
Eugene, Ore. — J. Francis Whitney, Eugene Water & Electric Board.
Everett, Wash.—C. V. Harlander, Snohomish County P.U.D. #1.
Forest Grove, Ore. — Dr. Mathew Alpern, Pacific University.
Great Falls, Mont. — Wilson E. Pickrell, 3212 First Ave. N.
Hillsboro, Ore. — James Hunt, Portland General Electric Co.
Klamath Falls, Ore. — Don F. Miller, P.O. Box 1194.
Lewiston, Idaho — James K. O'Toole, The Washington Water Power Co.
Medford, Ore.—Henry L. Bray, Trowbridge & Flynn Electric Co.
Mount Vernon, Wash.—Robert T. O'Conner, Puget Sound Power & Light Co.
Nanaimo, B. C.—S. G. Carlson, 1259 Townside Road.
Newberg, Ore.—Henry M. Carney, Jr., Portland General Electric Co.
Newport, Ore. — Dr. George W. Henderson, P.O. Box 68.
Olympia, Wash.—F. R. Starrett, Puget Sound Power & Light Co.
Oregon City, Ore. — D. A. Maulding, 122 Ogden Drive.
Oswego, Ore. — A. G. Miller, P.O. Box 176, Route 2.
Pullman, Wash.—Richard Harbour, 410 Fountain St.
Salem, Ore. — Elmo F. Lindhom, 136 S. High St.
Sandpoint, Idaho — Kenneth W. Anderson, Pacific Power & Light Co.
Seaside, Ore.—J. Dan Webster, Pacific Power & Light Co.
Trail, B. C.—Thomas Emes, Emes Electric Co.
Walla Walla, Wash.—Frank Gage, 825 S. Palouse.
Wenatchee, Wash.—R. F. Watt, Public Utility District #1 of Chelan County.
Winslow, Wash. — Frank M. Drebick, Puget Sound Power & Light Co.

Southern Region

Anderson, S. C. — F. R. Tollison, City Electric Co.
Anniston, Ala.—D. A. Springer, 22 E. 12th St.
Asheville, N. C.—C. T. Alley, Graybar Electric Co.
Athens, Ga.—R. A. Arthur, Georgia Power Co.
Atlanta, Ga.—H. L. McKinley, 657 Cresthill Ave. N. E.
Augusta, Ga.—Walter S. Smith, Jr., Georgia Power Co.
Baton Rouge, La. — Prof. W. D. Morris, Louisiana State University.
Baton Rouge, La.—J. A. Stelly, Gulf States Utilities.
Birmingham, Ala.—Elwyn B. Richey, Comer Bldg.
Charleston, S. C. — W. B. Leland, 4 Broad St.
Charlotte, N. C. — Richard C. Marshall, Jr., 401-A Wakefield Drive.
Chattanooga, Tenn.—Buford H. Martin, Tennessee Valley Authority.
Columbia, S. C. — N. L. Simmons, General Electric Co.
Columbus, Ga. — R. D. Hannah, Georgia Power Co.
Durham, N. C. — W. Earl Blackmon, Noland Co., Inc.
Florence, Ala.—Robert C. Willis, 1250 James St.
Fort Lauderdale, Fla.—Walter Dance, Broward Electric Service Inc.
Gainesville, Fla.—John W. Wilson, University of Florida.
Greensboro, N. C. — Charles C. Boyer, 3319 Wiltshire Drive.
Greenville, S. C. — R. F. Smathers, P.O. Box 276.
Griffin, Ga.—John B. Walton, Walton Electric Co.
Hickory, N. C.—Dan H. Ligon, Ligon Electric Supply Co.
High Point, N. C.—James S. Hunt, Electric Supply Inc.
Hollywood, Fla.—Jacob H. Blitzer, 1230 S. Lake Drive.
Jackson, Miss.—T. M. Salisbury, Gregory-Salisbury & Co.
Jacksonville, Fla.—Jess D. Thomas, Route 11, Box 751 G.
Kingsport, Tenn.—J. B. Carson, Kingsport Electric Co., Inc.
Knoxville, Tenn.—Leslie B. Pierson, Knoxville Utilities Board.
Lafayette, La.—John R. Gaugler, Gulf Public Service Co.
Lithonia, Ga.—James M. Russell, Lithonia Lighting Products Co.
Little Rock, Ark.—John S. Williams, Arkansas Power & Light Co.
Macon, Ga.—W. T. Cantrell, Georgia Power Co.
Mandarin, Fla. — J. N. Crevasse, Drawer 7.
Marietta, Ga. — P. N. Littlefield, Champion Lamp Co.
Memphis, Tenn. — Francis Whitesides, 999 Monroe.
Miami, Fla.—Prof. J. S. Sells, University of Miami.
Miami Beach, Fla.—Richard Poor, 1379 N. Venetian Way.
Milledgeville, Ga.—William F. Humbert, M. T. Stevens Southern.
Mobile, Ala.—J. D. Terrill, McGowin-Lyons Hardware & Supply Co.
Montgomery, Ala.—W. D. Parker, Alabama Power Co.
Nashville, Tenn.—Collin Finney, P.O. Box 27.
Orangeburg, S. C. — R. C. Dukes, Dukes & Dukes, Inc.
Orlando, Fla.—Geo. P. Yucius, Orlando Utilities Comm.
Raleigh, N. C.—Coy C. Jordan, Carolina Power & Light Co.
Rome, Ga.—W. T. Tucker, Georgia Power Co.
St. Petersburg, Fla.—J. Allyn Stone, Florida Power Corp.
Savannah, Ga.—W. C. Matthews, Savannah Electric & Power Co.
Southern Pines, N. C.—Paul C. Butler, Carolina Power & Light Co.
South Miami, Fla.—Edward C. Foerster, Foerster Electric Co.
Spartanburg, S. C. — I. C. Turner, Noland Co.
State College, Miss.—Prof. H. C. F. Simrall, Mississippi State College.
Tampa, Fla.—Gordon L. Priday, 4318 Rencilie Drive, S.
West Palm Beach, Fla. — Ray Cox, Florida Power & Light Co.
West Point, Ga.—Charles R. Williams, Heard Williams Co.
Wilmington, N. C. — William B. McGowen, Carolina Power & Light Co.
Winston-Salem, N. C. — George C. Hough, Graybar Electric Co.

South Pacific Coast Region

Fresno, Calif.—J. E. Hammond, Pacific Gas & Electric Co.
Long Beach, Calif. — L. M. Tilson, Southern California Edison Co.
San Bernardino, Calif.—William A. Lawrence, General Electric Supply Co.
Santa Ana, Calif.—J. W. Dickson, Southern California Edison Co.
Santa Barbara, Calif. — H. V. Dobson, 626 W. Islay St.
Santa Cruz, Calif.—L. Wollenberger, Coast Counties Gas & Electric Co.
Vallejo, Calif.—Norman A. Schiewe, Pacific Gas & Electric Co.

Southwestern Region

Alice, Texas—F. S. Gregory, Central Power & Light Co.
Amarillo, Texas—Thomas J. Lynn, Southwestern Public Service Co.
Bartlesville, Okla.—E. C. Postlewait, Public Service Co. of Oklahoma.
Beaumont, Texas — J. H. McClellan, Jr., Gulf States Utilities.
Chickasha, Okla. — John B. Harris, Public Service Co. of Oklahoma.
Corpus Christi, Texas—B. L. Guess, 1210 York Ave.
Elk City, Okla. — Dr. Russell M. Koch, 116 N. Jefferson.

(Continued on page 54A)

THERE'S SOMETHING FOR EVERYONE

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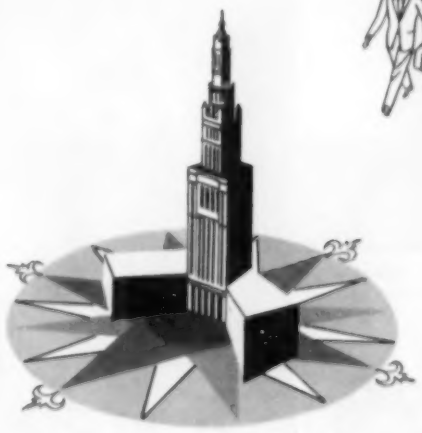
- ✓ Control and Use of Specular Reflections
- ✓ Cost and Comfort of Industrial Lighting
- ✓ Daylighting
- ✓ Discomfort Glare
- ✓ Electroluminescence
- ✓ Fluorescent Lighting in Cold Storage Areas
- ✓ Lighting Design Calculations
- ✓ Mercury Lamps
- ✓ Night Visibility of Roadway Obstacles
- ✓ Phosphor Characteristics
- ✓ Quartz Infrared Lamps
- ✓ Roadway Lighting
- ✓ Signboard Lighting
- ✓ Street Lighting Fixtures
- ✓ Summary of Street Lighting and Shadetree Conference
- ✓ Temperature Effects on Fluorescent Lamps
- ✓ Visibility of Office Tasks



These are some of the subjects to be covered... we checked everyone!

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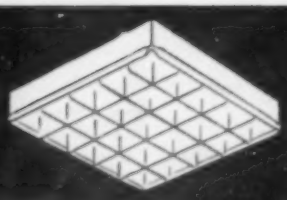

can do the job so well . . .

When it comes to Low brightness, large area light sources . . .

Another striking example of how LUVE-TILE provides the utmost in illuminated ceilings is shown in these photos of the Industrial National Bank of Detroit, Michigan.

LUVE-TILE is easy to maintain—dirt collection is much less rapid than with other types. . . and it will not hold insects and other smal matter. Because LUVE-TILE is hinged, servicing of fixtures is easy. LUVE-TILE is also rigid to handle, light in weight and easy to remove and wash.

LUVE-TILE may be assembled to suit any room and custom-made work is never necessary. No unsightly horizontal bars or rosettes are used for support. Since LUVE-TILE comes in 4 shades unlimited colour combinations are possible.

Sprinklers and air ducts are concealed and wiring and other work may be simply surface mounted. Also low cost acoustic material may be sprayed on the cavity above the tile for sound proofing. LUVE-TILE is practical and economical to use in any area, right down to a few square feet. It is also widely used in display for special effects.

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Architect and Engineer	Louis G. Redstone 10811 Puritan, Detroit
Contractor	Turner Engineering Company 470 Brainard, Detroit
Wholesaler	Michigan Chandelier, Company

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J. A. WILSON LIGHTING & DISPLAY INC.

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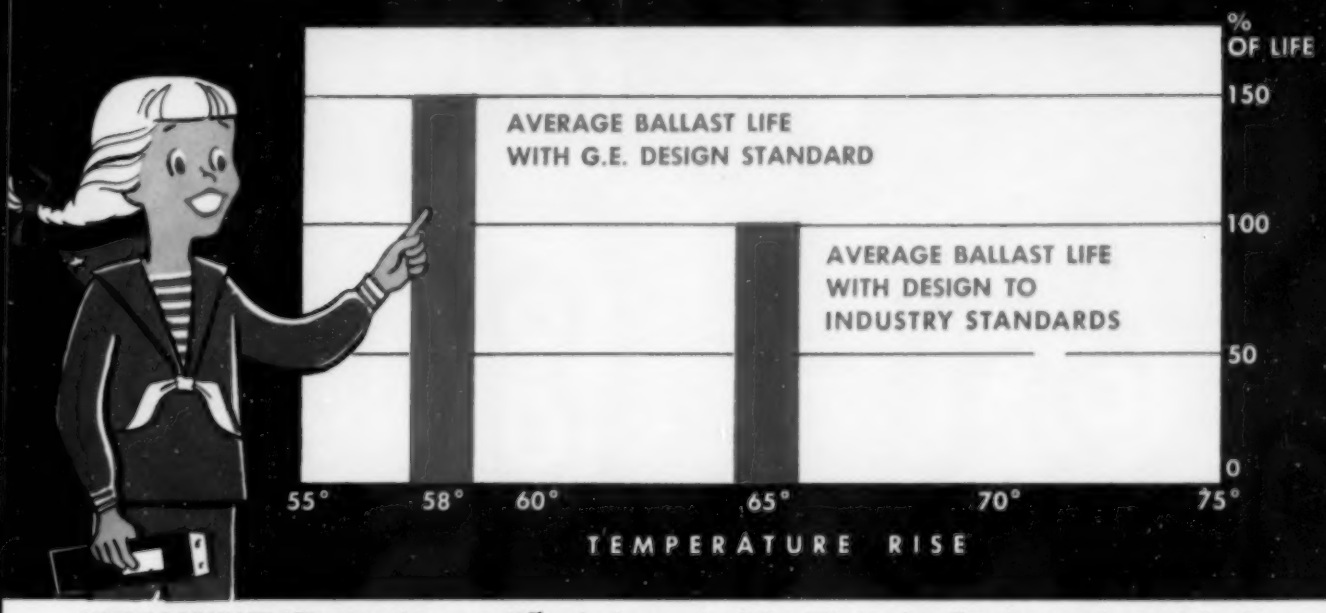
IN CANADA: 280 LAKESHORE ROAD, TORONTO, ONTARIO

G.E. gives you 50% more ballast life by designing 10% cooler than industry standards



BECAUSE G-E BALLASTS ARE engineered to operate 10% cooler than industry standards, they offer 50% longer life in your fluorescent installation. With this chart, Flora shows you the extra ballast life you get when you specify General Electric's cooler operating ballasts.

Flora* shows you why . . .

General Electric Ballasts Last 50% Longer, Help You Save Lighting Dollars

Every G-E ballast is designed to operate 10% cooler than industry standards; the chart above shows that this means 50% longer ballast life! To you, this means longer life for your fluorescent installations and a real saving in lighting dollars.

By carefully filling each ballast with a special heat-conducting compound, and by using larger wire size in the coil windings than would be required simply to meet industry standards, G.E. builds ballasts that operate cooler! Cooler operating temperatures combined with the use of unusually strong insulating materials results in years of added ballast life.

These special G-E techniques contribute toward lower operating temperatures, resulting in 50% longer ballast life.

Next time you specify equipment for a fluorescent lighting installation, make sure you get the best . . . specify General Electric longer-life ballasts.

A G-E ballast tag or sticker on your fixture is proof that it's equipped with a superior ballast; G-E ballasts in your installation mean better, more efficient lighting, more economical operation. For further information on G-E ballasts, write Section 401-10, General Electric Company, Schenectady 5, New York.

*Miss Fluorescent Ballast, G.E.'s Ballast Mascot

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G-E BALLASTS ARE constantly spot-checked for normal or abnormal temperature rise in this special lab. Close control of temperature rise helps assure 50% longer G-E ballast life.

Five more reasons why

GENERAL ELECTRIC IS YOUR BEST BALLAST VALUE

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- PRECISE LAMP-MATCHED DESIGN
- PROVED PRODUCT LEADERSHIP
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400W MERCURY VAPOR LAMP LIFE TEST INSTALLATION: This photograph, taken in a steel service shop of Joseph T. Ryerson & Son Inc., shows Sola Constant Wattage Mercury Vapor Lamp Transformers mounted in a pendant-type, high-bay installation. Ryerson industrial engineers checked this installation continuously to record increased lamp life arising from constant wattage ballast regulation.

Mercury Vapor Lamp Life Increased 50% with Sola Constant Wattage Transformers in Ryerson Test Installation

Getting the most mercury vapor lighting for your dollar demands consideration of factors other than lamp and transformer cost. Quality of illumination, long lamp life, and system reliability are essential for maximum efficiency and economy in mercury vapor lighting systems.

The pilot Sola-ballasted, mercury vapor lighting installation of Joseph T. Ryerson & Son Inc. shows the following advantages of *regulated* mercury vapor lamp operation: Increased lamp life, constant lumen output (often in the face of line voltage variations as great as 25%), reliability, and reduced system maintenance costs. Specifically, the following eight features can be yours when your mercury vapor lamps operate from Sola Constant Wattage Mercury Vapor Lamp Transformers:

1. *Constant light output within ±2% regardless of line voltage variations as great as 25%.*
2. *Lamps stay lit, even when line voltage drops as much as 40v (on 110v line).*
3. *Positive starting.*
4. *Elimination of primary taps.*
5. *Negligible starting current surge.*
6. *Protection on both open and short circuit.*
7. *Extended lamp life.*
8. *More ballasts can be installed on each circuit.*

These premium performance units are also available in a sealed housing for outdoor, weatherproof, commercial or industrial applications. They are particularly suitable for gasoline stations, plant protection, store fronts and parking lots.

COMPUTING LAMP LIFE: Here a Ryerson industrial engineer reads a service-hour register used to establish lamp life of the above installation. Lamp life is rated at 6,000 hours. At the conclusion of the test — 10,000 hours — 90% of the Sola-ballasted lamps were still operating. This is a lamp life extension of 50%.

Write for Bulletin 3D-MV-211 for Indoor Application data and Bulletin 3D-MV-208 for Outdoor Application data.

SOLA *Mercury Vapor Lamp* **TRANSFORMERS**

Regulated Outdoor

Regulated Indoor

Conventional Indoor

CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • LIGHTING TRANSFORMERS for All Types of Fluorescent and Mercury Vapor Lamps. • SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464 • PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4908 • BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354 CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400 • KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382 • Representatives in Principal Cities

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by Smithcraft

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This mounting bracket with simple clip attachments adapts the Smithcraft Troffer to a great majority of the ceilings in use today.

The new Smithcraft troffer-in-plaster frame method assures perfectly square plastered openings and is unbelievably simple to install.

Write today for the new Smithcraft Troffer Book illustrating and describing the new Smithcraft Troffers in detail.

Door frame containing glass, plastic or lens instantly opens or closes by simple pressure upwards.
In louvered units, louvers hinge from either side and are removed without tools or loose parts.
Smithcraft
LIGHTING DIVISION

"BUY LIGHTING" — *NOT FIXTURES* — INVEST IN AMERICA'S FINEST FLUORESCENT LIGHTING

It's easier to sell when it's easier to see!

Every store owner knows that his cash register gets more day-to-day action when he uses light as an *effective* selling "tool."

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These men know store lighting. That's their business. Their service starts with your "selling-through-seeing" problems — carries all the way through to the final installation that leads to easier selling through easier seeing.

If you have any doubt or question about your store lighting call a Day-Brite store-lighting representative. There's one near you. He's ready at all times to advise you on the most effective—and economical—way to light *your* store for sales!

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5440

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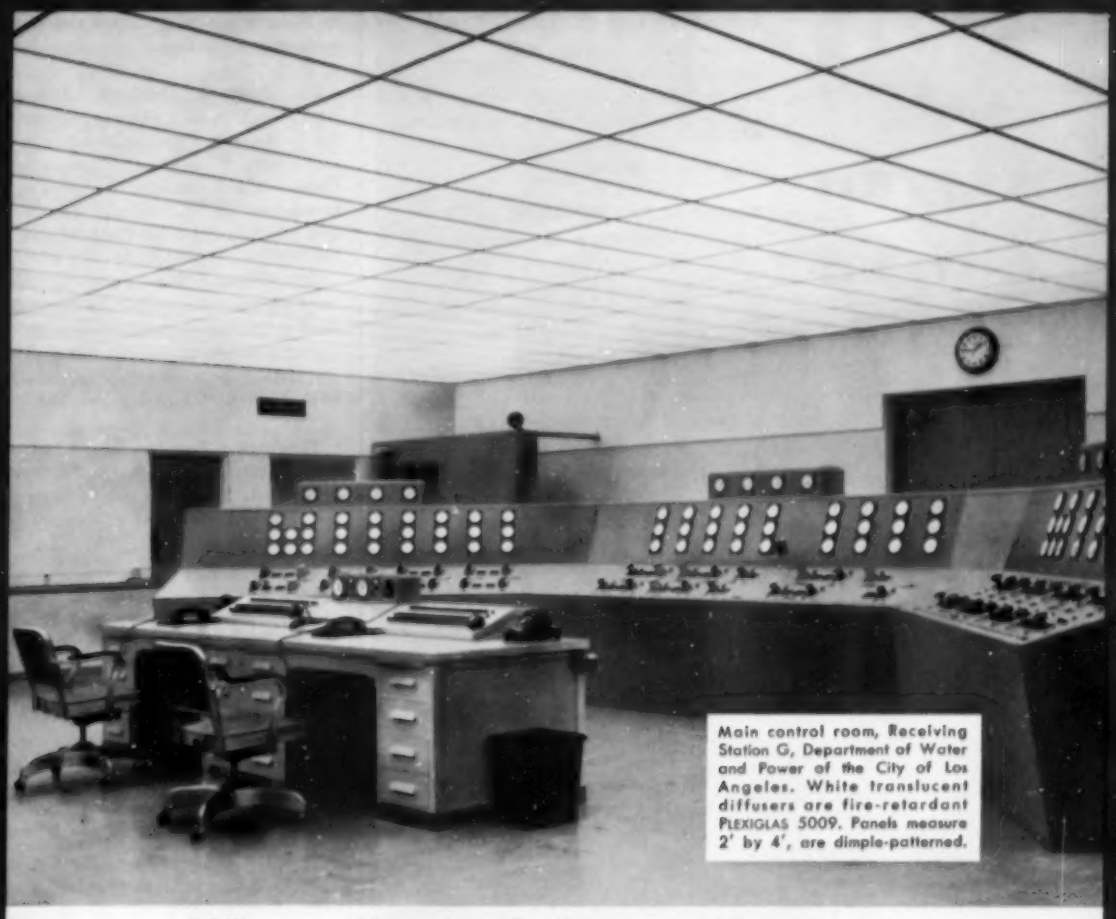

Main control room, Receiving Station G, Department of Water and Power of the City of Los Angeles. White translucent diffusers are fire-retardant PLEXIGLAS 5009. Panels measure 2' by 4', are dimple-patterned.

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This control room requires lighting of the highest quality, because the seeing tasks involved in the constant reading of instruments and keeping of records are complex and exacting.

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DESIGNERS AND MANUFACTURERS OF THE FINEST IN LIGHTING

(Continued from page 18A)

made known the appointment of **Robert B. Nieman** as Cincinnati, Ohio, district sales representative.

Dr. Richard Feinberg, President, Northern Illinois College of Optometry has been selected for membership on two committees of the Chicago Association of Commerce and Industry: to serve on the Committee on Educational Institutions and the Committee on Civic Affairs.

Kliegl Bros., New York, N. Y. announces the appointment to its staff of **Joel E. Rubin** as design associate specializing in educational theater problems. Mr. Rubin is a co-author of the text book *Theatrical Lighting Practice.*

Sheppard Cohen has joined the engineering staff of Starring & Co., Bridgeport, Conn. Mr. Cohen was formerly with the Ballast Department of General Electric Co., in Danville, Ill., and Fort Wayne, Ind.

Starring & Co., also announced the appointment of **Murray Rosenblum & Co.,** as their mid-west sales representatives. Mr. Rosenblum will be assisted by **William M. Brown,** acting as general sales manager.

Deaths

Sections and Chapters of I.E.S. report with sorrow the deaths of the following members:

W. D. Gorman, West Hartford, Conn., Connecticut Section.

Leslie W. Slade, Electrical Engineer, Edward L. Varney Associates, Phoenix, Ariz., Arizona Section.

BOOKS AND PAMPHLETS

Books whose reviews are marked • are available for inspection at IES Headquarters, Technical Department.

•**Theatrical Lighting Practice,** by Joel E. Rubin and Leland H. Watson, published by Theatre Arts Books, New York, N. Y. 142 pages, indexed. $3.75

This book is intended to present material supplementing information on theater lighting in basic texts, as a handbook of advanced lighting practices and production criteria. Types of theater lighting covered include that for proscenium style for drama and musicals, ballet and modern dance and the opera stage; arena production for musicals, legitimate drama and ice shows; amphitheaters and aqua-theaters; puppetry; and television. Plans and light plots are given with discussion

of the use of color and techniques for these specific areas.

One section of the book covers job opportunities for a lighting engineer in the field of theater lighting in both commercial work, including television, and semi-professional and educational theater. Appendices include a bibliography and a directory of manufacturers of theater lighting equipment.

There is a Preface by Stanley McCandless, with whom both the authors did graduate work at the Yale University Department of Drama. Mr. Rubin is at present with Kliegl Brothers; Mr. Watson is a staff lighting director with CBS Television.

Abstracts of the Literature on Semiconducting and Luminescent Materials and Their Applications. Published by John Wiley & Sons, Inc., New York, N. Y. 169 pages, spiral-bound in 8½ x 11-inch format. Indexed. $5.00.

This bibliography was compiled by personnel of the Battelle Memorial Institute, and as one of a series, is sponsored by the Electrochemical Society. Contributions included are from metallurgy, ceramics, chemistry, physics, electrochemistry, and electrical, chemical and mechanical engineering. Materials considered are: germanium, silicon, carbon and diamond, boron, gray tin, antimony and phosphorus, selenium and tellurium. Individual sections are devoted to luminescence and phosphorus and semiconductor theory.

RLM Standard Specifications, 1955 edition, have been established for both incandescent and fluorescent industrial lighting units. Twelve features of the revised standards are: Increased upward light; all-white porcelain enameled fluorescent reflectors; maximum brightness specifications; shielding angles of 13-14° on direct and totally-direct fluorescent units and 27° on semi-direct; higher reflection factors; higher light output, captive latching and holding devices; grounded ballast mounting; channel construction for sliding hangers; revised lamp spacing; improved lampholders, and rust-proofing. Copies of the specification book can be obtained from the RLM Standards Institute, Inc., 326 West Madison St., Chicago 6, Ill.

Lighting Terminology for TV Studio Lighting. Published by the Society of Motion Picture and Television Engineers, New York, N. Y. Free.

A uniform lighting terminology worked out by the Television Studio Lighting

(Continued on page 50A)

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(Continued from page 49A)

Committee of SMPTE has been begun with a list of ten terms which have been defined for standardization of the language in this field. The list is being compiled by the Committee with the help of a majority of the nation's TV stations.

Outdoor Lighting for Your Farm. Published by Sylvania Electric Products Inc. Free.

Some of the subjects covered are circuits power distribution centers, pointers on planning outdoor lighting, wiring systems, selection of fixtures and types of lamps for outdoor use. Photographs and sketches illustrate some installations. There is a section on lights for special purposes such as the control of plant breeding and the trapping of crop-destroying insects.

List of American Standards, 1955 Edition. Published by the American Standards Association, 70 E. 45th St., New York, N. Y. 48 pages. Free.

About 1500 American Standards are listed and indexed, including 210 for construction and civil engineering; 153 mechanical; 272 electrical; 158 safety; 251 photography and motion pictures.

NEW MEMBERS

At the meeting of the I.E.S. Council Executive Committe held in New York, N. Y. on January 14, 1955, the following were elected to membership. Names marked * are transfers from Associate Member grade.

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*Phillips, J. L., 348 Brown Marx Bldg., Birmingham, Ala.

*Britton, F. H., Jr., Alabama Power Co., Birmingham, Ala.

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Crosby, W. F., Jr., Corning Glass Works, Corning, N. Y.

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Contos, P. G., City of Chicago, Bureau of Electricity, Chicago, Ill.

Denny, F. F., General Electric Co., Chicago, Ill.

Dwyer, B. J., General Electric Co., Chicago, Ill.

Hinkey, W. H., Public Service Co., Div. of Commonwealth Edison, Harvey, Ill.

Melcher, Louis, Jr., Childs & Smith, Chicago, Ill.

Nagel, R. I., Elastic Stop Nut Corp. of America, Chicago, Ill.

Nocchi, D. W., Public Service Co., Div. of Commonwealth Edison, Maywood, Ill.

Wolfson, R. A., 608 So. Dearborn St., Chicago, Ill.

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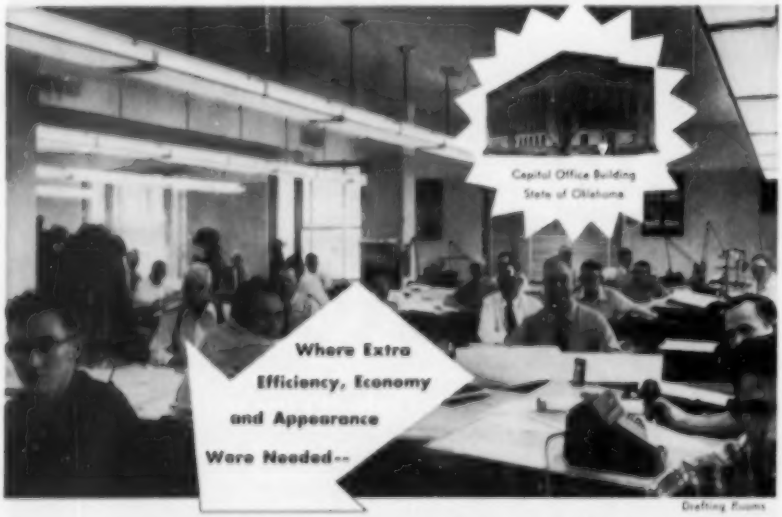

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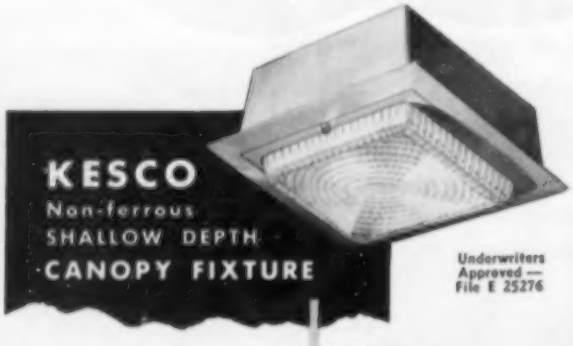

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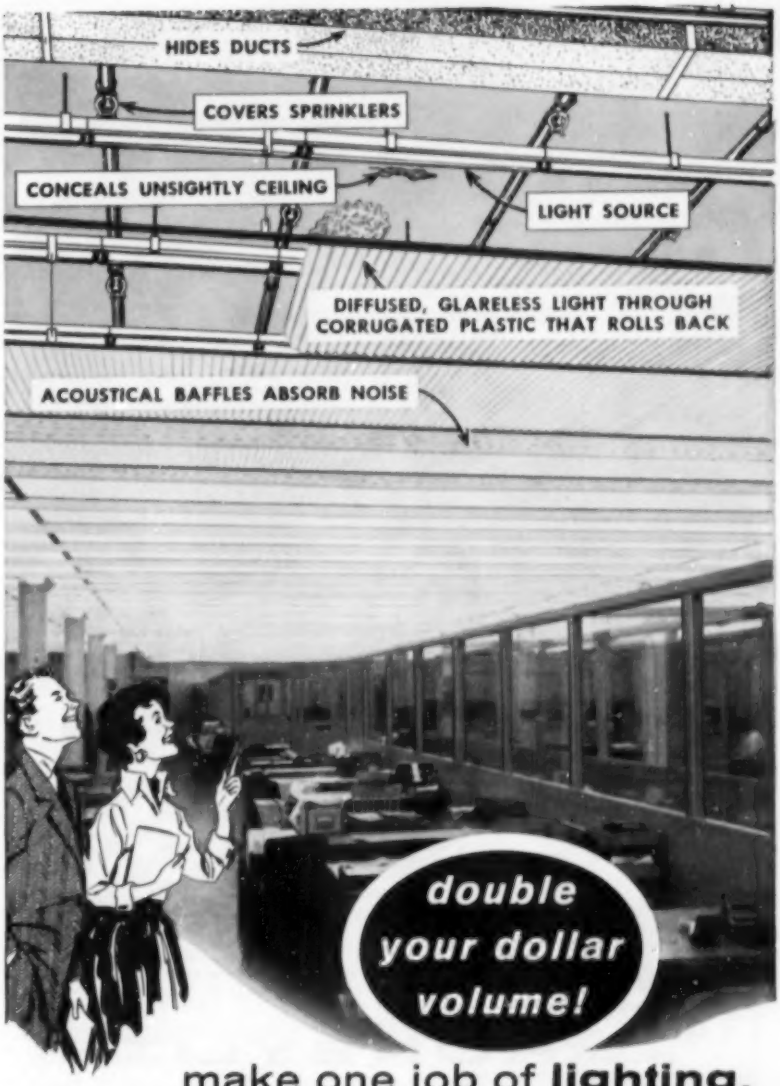

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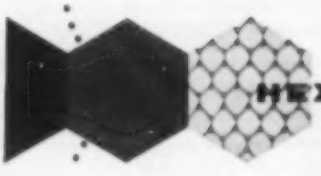

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(Continued from page 40A)

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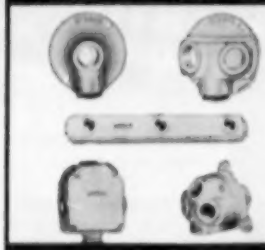

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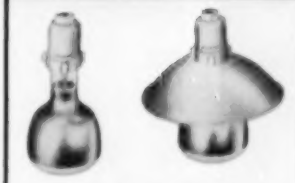

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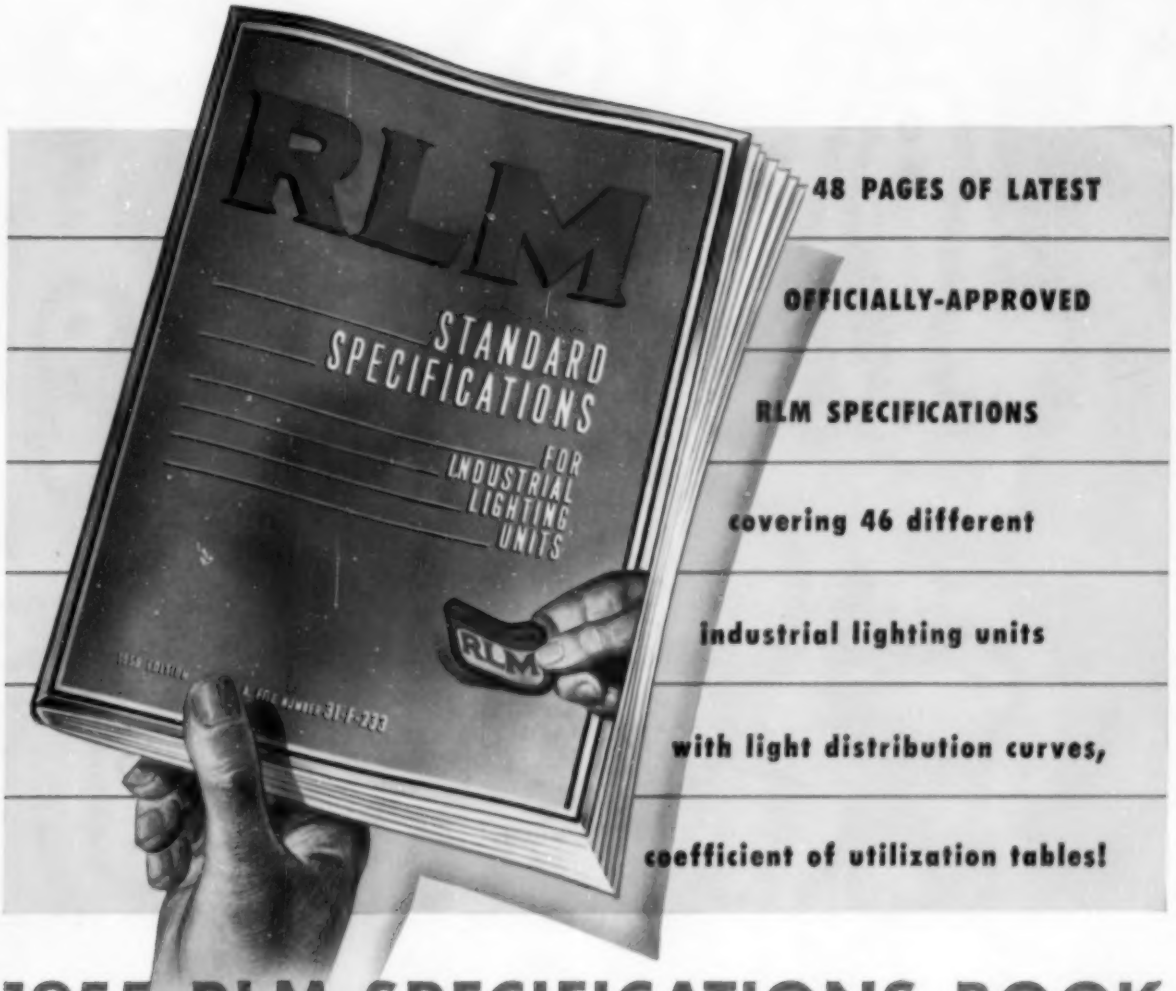

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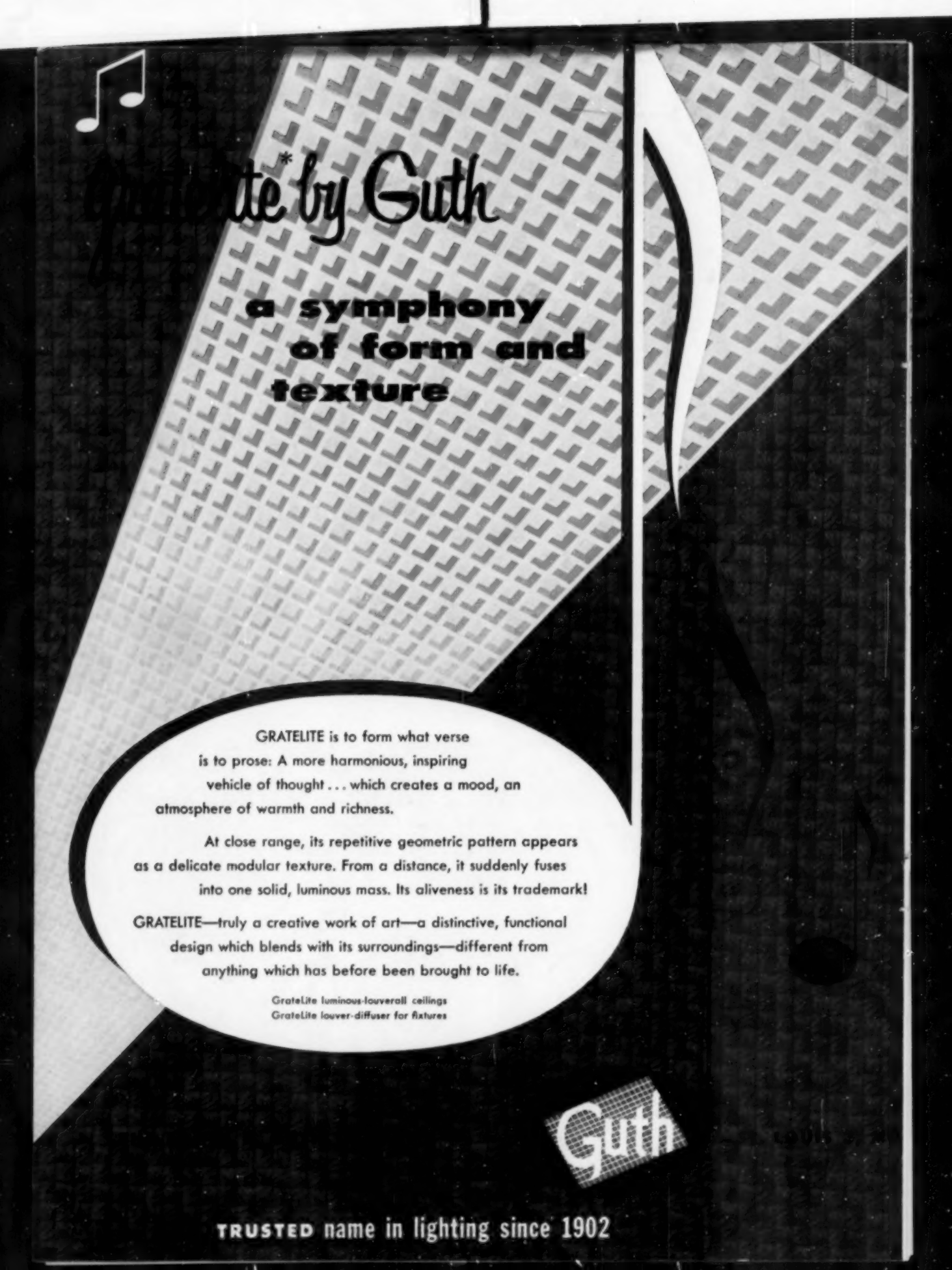
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